AGRICULTURE IN THE SUDAN

Being

A HANDBOOK OF AGRICULTURE AS PRACTISED IN THE ANGLO-EGYPTIAN SUDAN

BY

NUMEROUS AUTHORS

EDITED BY

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and from January 1939 to May 1944
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'Of all occupations from which gain is secured, there is none better than agriculture, nothing more productive, nothing sweeter, nothing more worthy of a free man.'

Cicero, de Officiis, Bk. 1, *Sec.* 42.

'Take not too much of a land, weare not out all the fatnesse, but leave it in some heart.'

Holland's Translation of
Pliny's 'Historia Naturae,' p. 586.

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DEDICATED TO

THE MEMORY OF THE LATE

SIR DOUGLAS NEWBOLD

K.B.E., 3 N

who inspired all who were privileged to work under and with him and at whose suggestion this book was undertaken

PREFACE

By MAJOR-GENERAL SIR HUBERT HUDDLESTON
K.C.M.G., C.B., D.S.O., M.C.
The Governor-General of the Anglo-Egyptian Sudan

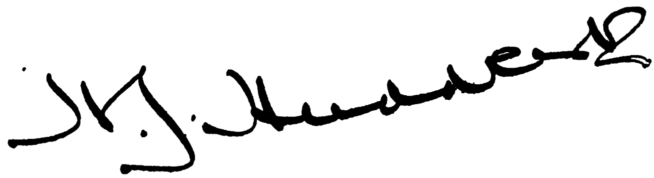
WE have waited a long time for this book, but it was worth waiting for. The Editor is Dr. J. D. Tothill, C.M.G., whose long experience in Agricultural Research both in the United States and the British Empire makes him peculiarly well fitted for the task.

From the Intelligent Tourist on the one hand to the Professional Agriculturist at the other extreme this book will be of inestimable value and no subject of agricultural importance is omitted.

The Editor has welded his twenty-eight separate authors into a well-matched team. To handle the reins of a twenty-eight in hand and drive it down the middle of the highway without deviating into the many tempting byways which open up at every turn is no easy task, but it is one that the Editor has performed admirably. He has produced a really well-balanced Book of Reference in which everything that is necessary for the ordinary man to know on the subject is included. The various authors have dealt with their respective subjects concisely, and there is no sign of that diffuseness which not infrequently mars books of this type where each author not unnaturally desires to write with great detail on his own peculiar subject.

I fully share the Editor's view that the future of the Sudan as far as it can be predicted must lie in agriculture. If that is so it is essential that every member of the Government from the highest to the lowest should have a sound knowledge of the general principles of agriculture as practised in the Sudan to-day, and not only Government officials but the general public as well. Without such knowledge nobody, whether he is a townsman or a countryman, can be a complete citizen, and it is the lack of such knowledge that has caused that neglect of agriculture which has marked the recent history of far too many countries. Now that this book has been published nobody in the Sudan will have any excuse for further ignorance.

I cannot conclude this preface without congratulating the Editor and all the various contributors who between them have made a noteworthy addition to the technical literature of the Sudan.



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CHAPTER I

INTRODUCTION

By J. D. TOTHILL, C.M.G., D.SC. B.S.A.
Principal of Gordon Memorial College

WHY THE BOOK WAS UNDERTAKEN AND WHAT IT IS INTENDED TO BE

THE planning of this Handbook was commenced in 1941. The late Sir Douglas Newbold, K.B.E., 3 N., had seen the first copy of the *Uganda Agricultural Handbook* to reach the Sudan and sent me a note of appreciation suggesting that a *Sudan Handbook of Agriculture* would be a useful addition to the literature of the country and asking me to consider the production of such a volume. His Excellency the Governor-General, General Sir Hubert Huddleston, K.C.M.G., C.B., D.S.O., M.C., endorsed this suggestion. Various people were then asked for an opinion and it was generally agreed that such a volume would be welcome.

A glance at the bibliographies will serve to show that a good deal has been published about agricultural matters. Coming to the Sudan early in 1939 as Director of Agriculture and Forests and as a stranger to the country I found it difficult, however, to read up the story of agricultural progress, and of related sciences, because there was no general work of reference. The reading had to be done in numerous technical journals and in Government files; and in the case of some subjects such as Archaeology and Geology, both vital for a proper understanding of the soils of the Sudan, there were no useful summaries even in the files. Members of the London Advisory Committee on agricultural research were also constantly asking questions about the Sudan, the answers to which could suitably be included in a general work of reference.

The volume was commenced, therefore, in the belief that an authoritative work of reference would be of value not only to persons directly concerned with shaping policy but also to many people working in the Sudan; and that it might also help people who do not know the Sudan intimately, but who are interested in local problems, to understand the sort of country it is in which these problems have to be solved.

The book is intended to be an authoritative but non-technical work of reference containing a number of background chapters, all of which in one way or another help the reader to understand the varied sorts of agriculture practised in a country that extends from rainless desert to tropical rain forest; from the trade-wind zone to the doldrums; from irrigation to rain agriculture; from settled areas to places where only Bedouin tribes can live; and in elevation from 408 ft. above mean sea-level at Wadi Halfa to 10,000 ft. more or less on Jebel Marra and Mount Kineti.

The first provisional outline was drawn up in May 1941 and most of the typescript handed to the publishers in August 1945. It has, therefore,

been four years in preparation. Most of the chapters were written by their respective authors during the press of war, mainly during holidays and in out-of-office hours, as a relaxation from the crowded, urgent duties of that extraordinarily difficult period.

An attempt has been made throughout to use only direct, simple, non-technical English. In the chapters dealing with technical subjects, such as the long one on agricultural research and the shorter ones on geology and botany, this has not been easy and some technicalities have been introduced. It is hoped, however, that the explanations and footnotes will enable the general reader to read and understand even these chapters on technical subjects.

The authors are numerous and selected wholly from the point of view of producing the best possible volume.[1]

In scope the volume is intended to give a picture of progress or otherwise made in the agricultural life of the country from the time of Lord Kitchener's reoccupation in 1898 to June 1945.

Agricultural Policy of the Sudan

In the introductions to the Province chapters will be found historical notes which serve as a reminder that prior to the reoccupation there was neither peace nor security in most rural areas and that many tribes with their crops and domestic animals were constantly attacked by the slave-raiders. The agricultural policy of that period was the negative one of growing as little as possible and that little only in places that could be defended at short notice.

In the 47 years of peace that have followed policy has been devoted to healing the terrible wounds inflicted, sometimes on whole tribes, and in preparing for better days to come. The agricultural policy in the narrow sense was to grow more food over greater areas and in greater variety; in the broader sense to provide the foundation for the social emergence of the Sudanese people.

After this long interval of peace and as a result of the policy pursued it is to-day possible to lay far more emphasis on social emergence, and this conception has now become the unifying principle in the agricultural policy in, for instance, Tokar, the Gash, the Northern Province 'sāqiya' lands and pump schemes, the Gezira, the White Nile pump schemes both private and government, the rain lands of Kassala, Blue Nile, Upper Nile, Kordofan, Darfur, and Equatoria Provinces.

To amplify this a little the present agricultural policy of the Sudan may be said to be designed to bring about the social emergence of rural communities. Food crops are encouraged which are designed to produce an ample food-supply and a well-balanced diet; the production of an adequate milk-supply is almost as important; the provision of good drinking-water and of fuel and of building poles is also encouraged. With these things satisfied the emphasis is placed on a cash crop to be fitted into the rotation; this crop is designed to produce money to enable the cultivators to pay taxes

[1] Two of the ablest contributors, A. Lucas and F. Crowther, died during the preparation of the volume, and it is sad that their chapters have to be published posthumously.

and to purchase those trade goods required for participation in the benefits of civilization. The aim is to bring about the emergence of happy and prosperous rural communities rapidly becoming fully literate, financially able and mentally wishing to participate in the advance of civilization and taking an ever-increasing interest in the management of their own affairs.

The effect of the use of this touchstone of social emergence can be seen in the recent revision of the land allotments at Tokar; in the re-designing of the rotations in the Northern Province pump schemes, particularly Bouga; in plans made for the development of the citrus and date industries; in the decision to change the working arrangements for the Gezira scheme as from 1950; in the plans for the Zande experiment in Equatoria Province; in many decisions of the Nile Pumps Control Board; and in examining the problem of land fractionation.

This is no new principle in the Sudan as it goes back almost to the early days of the reoccupation. The re-examination of policy necessitated by the stresses and testing of five years of war has, however, served to emphasize the fact that the social emergence of rural populations is the basis of the agricultural policy and that it has become more than ever important now that so many of the old wounds of slave-raiding days are healed or healing. It is now possible to contemplate the process of emergence proceeding at a somewhat quicker pace—although by definition it can proceed only *pari passu* with education.

THE STATE OF CIVILIZATION NOW REACHED IN RURAL SUDAN

In the chapters on land fractionation and on Darfur Province some indication is given of the housing, food, and living conditions for a poor rural community and for a community that would be considered well off in almost any part of tropical Africa. In the Northern Province chapter some details are given for the comparatively prosperous population of the Bouga pump scheme. These few details are the only ones available so far because shortage of staff due to the war prevented more village surveys being made. They serve, however, to give some indication of the living conditions of cultivators over fairly wide areas in the Sudan at the present time.

Were one to adopt money as the yardstick and to use western standards, the conclusion would be that the entire rural population is miserably poor. Such a conclusion would, however, be wide of the mark. The people in the Darfur village referred to and at Bouga are, as compared to many people in Europe, extremely well off: for the poorest people there is peace and security and sunshine; there is an ample food-supply and a good variety of foods; milk and good water and fuel for cooking are available to all; houses are plentiful and in a good state of repair; cotton for clothing materials can be grown and spun and woven. There is, in fact, no shortage of anything that is vital for the material comfort of a household. It might perhaps be said that in many parts of the Sudan a satisfactory physical and material basis for civilization has been achieved and that the stage is now set for spiritual, ethical, and moral advances in social evolution that may be expected to result from introducing education more widely to peoples having so secure a material foundation for their well being.

Type of Civilization possible in an Agricultural Country

It has taken 47 years to build the foundation and the superstructure is beginning to take shape. It is sometimes said that the Sudan is doomed for ever to be poor because in commercial quantities there are neither coal, nor oil, nor iron, nor minerals, and agriculture and forests are the only possible sources of wealth. Perhaps this lack of minerals is a blessing. There is certainly no valid reason for supposing that a purely agricultural country cannot achieve the highest type of civilization because there are the ancient examples of Greece and Italy and Egypt and the modern examples of Holland and Denmark and New Zealand. I personally see no grounds for pessimism and see no reason why a highly civilized state cannot be evolved in the Sudan on a purely agricultural foundation. It should, however, be understood that agricultural communities have to be hardworking and industrious and intelligent to be successful and that a great deal of hard work will be required in the Sudan if a high degree of civilization is to be achieved.

Soil Erosion and Desiccation

Very little is said in this volume about soil erosion because the whole subject was recently reviewed by the Soil Conservation Committee, the report of which was published in 1944. The recommendations of this Committee were agreed to in full by the Government and a Board is now at work putting the recommendations into practice. The Committee reviewed the evidence for and against the desiccation of the African continent, in so far as the Sudan is concerned, and came to the conclusion that there has been no change in basic climate since the beginning of Egyptian Dynastic times; and that where erosion is taking place it is caused by man and his domestic animals and that if taken in time it can be controlled. This conclusion is of great importance as it means that funds can be invested, and that orderly development can proceed, in the reasonable certainty that the agricultural lands of the Sudan will remain productive in perpetuity so long as reasonable steps are taken to prevent soil erosion.

Prior to Egyptian Dynastic, but within glacial or Pleistocene times, the basic climate of Khartoum has sometimes been much drier and sometimes much wetter than it is to-day and these changes in basic climate have had a great effect in producing the sands and the silts and the clays which together form the agricultural soils of the Sudan. These changes are referred to in the chapters on geology and on the origin of soils, and the evidence for some of the more recent changes has been reviewed by Tothill in a paper on the 'Origin of the Gezira Soil' (*Sudan Notes and Records*, vol. xxvii, 1946). In considering the questions of the desiccation of the African continent and of desert creep, for which there is good evidence in some parts of Africa, it is necessary in the Sudan sharply to distinguish the remnants of the Pleistocene deserts as represented by the now anchored Kordofan and Darfur 'qōz' from such features as the unanchored desert sands lying to the northward of Kareima.

Explanation of Terms

The terms 'cotton soil' and 'black cotton soil' are widely used in the Sudan, but for the following reasons are not used in this book. Christie, writing more than a century ago, seems to have been the first to describe what he called the 'regur' or 'cotton-ground' of India. Under the heading 'Cotton Ground' he says:[1]

'Immense deposits of a black alluvial clay are met with in various parts of India. It is denominated cotton ground from the circumstance of that plant being always cultivated upon it. It is the regur soil of the Ryuts. It forms large plains throughout the whole of the Decan; some of them sufficiently extensive to bring to mind the description given by travellers of the Pampas of South America, or the Steppes of Russia.

'Its depth extends from two or three to twenty or thirty feet. Its colour is greyish black or brownish black. In many places it is perfectly unmixed with any foreign ingredient. In this instance it contains nodules of calcareous tufa (well known by the name of kunkur in India) agates, calcedony, and occasionally also zeolites. In the hot season it is everywhere traversed by deep fissures; which, in some cases, have a great appearance of regularity like that observed in dried starch; but most commonly they are perfectly irregular. The late Dr. Voysey, when at Hydrabad, subjected some of this clay or cotton ground to the heat of a steel furnace, which fused it into a black glass.

'The black colour of this clay, the carbonate of lime, agates, and zeolites found in it, and its conversion into a black glass by heat, all indicate that it has originated from the disintegration of trap rocks. The extensive distribution of the trap rocks makes this inference still more conclusive. The soil which covers the trap hills and which we are certain has originated from the disintegration of the subjacent rock, exactly resembles the cotton ground of the extensive plains.'

While the expression 'cotton ground', since become 'cotton soil', is clearly apt and useful as applied to the trap rock derived alluvial clay plains of India, it is equally clear that it cannot properly be applied to the cracking clays of the Sudan, few of which are derived from trap rocks and only some of which are alluvial. In this book, therefore, the expression 'cracking clay' is used to describe the dominant soil of the great clay plain of the Sudan. This clay varies greatly in origin and in salt content but always has a high clay content and a strongly developed cracking system in the dry season. Cotton and dura do well on this cracking clay provided that rainfall or irrigation water is adequate, and provided that salt concentrations and permeability are satisfactory; these crops do equally well, however, on the red soils of Equatoria Province, and the recent silts of the Gash and Tokar deltas, and cannot therefore be used as an index.

The expression 'cracking clay' as used in this volume includes such diverse soils as the basin clays and those of the Sudd periphery,[2] both probably laid down under water; also the Gezira clay thought to have been laid down at the time of the annual flood of the Blue Nile; and great areas of non-alluvial clays resulting from the rotting of underlying rock. As time goes on it may well prove convenient to give special names to the more important of these different kinds of Sudan cracking clay.

[1] A. T. Christie, M.D., *Edinb. New Phil. Journ.*, Oct. 1828 to March 1829, p. 119.

[2] Sudd periphery is here used to indicate the substantial marginal area of clay plain around the existing Sudd thought to have been deposited under water in the days of a greater Lake Sudd.

The expression 'fallow' has been used in publications on the Gezira in a wide sense so as to include land that has been neither ploughed nor cultivated. As recent work, particularly by Crowther, has shown that the ploughing and cultivation of resting land in the Gezira have a marked effect on its fertility and particularly upon its content of available nitrogen, it has seemed better in this handbook to confine the use of 'fallow' to its narrow classical meaning of cultivated but uncropped resting land.[1] Uncultivated resting land in the Gezira rotation and elsewhere is referred to as 'resting' or 'resting land', and sometimes to break the monotony as 'bor' which is the local Arabic word for this sort of land. Some of us will miss the euphonious 'fallow–fallow–cotton' of the Gezira rotations, but perhaps we may grow accustomed to 'resting–resting–cotton' and the change will certainly describe the rotation more accurately and leave 'fallow' available for cultivated resting land. 'Resting land' also plays an important part in the natural rotation of rain lands in the Sudan and it seems right to use for this land the same expression as is used in the Gezira.

Some Changes in Scientific Names of Common Trees

One of the penalties of living in the twentieth century is that rapid transport has enabled systematists to examine a great deal of material connecting extreme forms of plants and animals. Some species thought to have been distinct have as a result been shown to be extreme forms of the same species. Our old friend *Acacia suma* Kurz. has been shown to be a northern dwarf variety of the much larger *Acacia campylacantha* Hochst. of the broad-leaved forest zone, and as the latter is the older name it must be used. The name for 'kuk' which most of us have known as *Acacia verugera* Schweinf. disappears for a similar reason in favour of *Acacia sieberiana* DC. The commercial gum tree that has been known in the Sudan as *Acacia verek* G.P. becomes *Acacia senegal* Willd. There are some others, and a list of the main changes established so far in the case of well-known plants will be found at the end of the chapter on Flora. It has seemed better to make these changes now rather than to extend the use of names that will vanish in any case when the new *Flora of the Sudan* is eventually published.

In the other direction it has been thought better to retain for dura the classical and universally understood name *Sorghum vulgare* Pers. In the flora of West Africa the great millets are described under a number of separate species and Snowdon has followed this classification. No genetical study of the sorghums and related grasses has been published, however, and it may well be that some of the species of authors will prove to be varieties when this additional information becomes available. S. H. Evelyn, who is studying the millets in the Sudan, has a paper on this subject in prepara-

[1] In Holland's translation of Pliny's *Historia Naturae*, so full of agricultural wisdom and published in 1634, the centuries-old meaning of fallow is made particularly clear. Some passages are as follows: 'In the warmer countries lands would be broken up and fallowes made immediately after the winter solstice' (l.c., p. 578). Again: 'After the second fallow called stirring, done with crosse and overthwart furrow to the first, then followeth clodding, if need be either with rakes or great harrowes' (l.c., p. 578). And again (l.c., p. 581): 'Virgil is of the opinion that fallowes would be made every yere: and surely I do find this rule of his most true.'

tion,[1] and will give genetical reasons for regarding all the duras as one species. He writes:[2]

'Johnson grass with its $2n = 40$ chromosomes crosses with the common $2n = 20$ chromosome types pretty easily and is probably just a diploid variety. In the Belgian Congo quite a few transitional forms between the common varieties and Broom corn occur and there is no reason to suppose that Broom corn is a separate species. The wild and semi-wild grasses known as 'adār' and 'ankolib' also cross very easily with each other and the cultivated forms and are all $2n = 20$ chromosome types. I think there is little doubt of their all being the one species with a common home of origin.'

Treatment of Arabic Words

There is no agreement among the pundits as to the best method of rendering Arabic words into English, but it has been necessary for the Editor to adopt a system of some sort for the sake of uniformity, and the one finally adopted for this volume is as follows:

(*a*) Place-names where given are spelled as in the Survey Department *Index Gazetteer* published in 1931. This also sets a standard for printing the letter 'ain' and for spelling of the words 'Umm' and 'Abd el' and 'Qōz'.

(*b*) Words like rotl, ardeb, feddan, sunt, and dura which are given in one or other of the big dictionaries of the English language, of which Funk and Wagnalls and Murray have been available in Khartoum, are treated as English words and given English plurals such as rotls, ardebs, and feddans. As the English language is constantly growing and adopting more Arabic words, this list is expanding rapidly with usage.

(*c*) Words like haboob and haboobs, teras and terasses, and lubia which are coming into the English language through local usage and technical literature have not been admitted as they have not yet been included in a big dictionary.

(*d*) Arabic words not given in one of the big dictionaries are treated as Arabic words, given an Arabic plural, and transliterated from the classical spelling. They are uncapitalized, in roman type, and put in quotation marks. Examples are 'lubia', 'bamia', 'qōz', 'teras', and 'terūs'. Where a long accent may help to indicate pronunciation it has been added, i.e. 'habūb', 'terūs', and 'nagīl'. The Arabic letter *ya* has been rendered *ī* where the sound is long, i.e. 'nagīl', and *iy* where the *y* sound is heard, i.e. 'sāqiya'.

(*e*) The rule adopted under (*b*) is broken in the case of the word 'sāqiya', which is given in F. and W. as sakieh, as this seems more suited to the French than the English language.

Illustrations

In the case of photographs the photographer's name is given wherever known. All diagrams are the work of the author of the chapter concerned unless otherwise stated. The original maps were produced by the Survey

[1] Due to appear in the *Journal of Genetics*, 1946.

[2] In a letter dated 25 April 1945, the substance of which he has authorized me to publish.

Department; they have in some cases been redrawn or otherwise treated by the publishers to make them suitable for publication in this volume.

ACKNOWLEDGEMENTS

As Editor I owe a debt of gratitude to all those who have contributed articles or chapters for the book. Much of the work, perhaps most of it, has been done in spare time and out-of-office hours and it has been doubly difficult to do this in the midst of war. To many friends whose names do not appear who have given advice and helpful criticism at innumerable points, I also wish to record my grateful thanks. Some beautiful photographs have been made available by J. F. E. Bloss and R. G. Fiddes and others, and to all who have contributed I record my sense of appreciation. The original maps were prepared by the Survey Department, and it is a pleasure to acknowledge the kindly help that has been given. The publishers have been at great pains to put right many of the imperfections of the typescript as handed to them by me, and I thank them for their unfailing help in endeavouring to produce the best possible volume with the fewest possible errors. My wife has helped me with the page proofing, and the help given is gratefully acknowledged.

RESPONSIBILITIES

In order to give the greatest possible freedom to individual authors the Sudan Government, while encouraging in every possible way the production of the book, accepts no responsibility whatever for anything said in the volume.

Individual authors are entirely responsible for the material appearing under their names. No amendments other than clerical ones have been made by the Editor that have not been agreed to by the authors. Any editorial comment on points in articles is made in the form of Editor's footnotes so that their authorship is clear.

The Editor is responsible for all the blemishes and imperfections including sins of omission and of commission. He is responsible for the plan and layout and method of treatment of the material, for co-ordination, and for the avoidance of unnecessary duplication.

FINAL PARAGRAPH

The editing has been done mostly between 6 a.m. and 8 a.m. when the air in Khartoum is cool and clear and when the birds in the garden are in full song. It has been a pleasant labour. To me, a comparative stranger to the Sudan, the book tells a remarkable story of sound agricultural progress, and the scientific battles against pests and diseases that have been fought and won at the Gezira Research Farm are highlights in the story. Personally I believe in the Sudan and that the social emergence into a highly civilized country is possible, provided that it is based solidly upon the productions of the soil and that the pace of evolution is not forced beyond the rate at which all steps taken can first be tested experimentally. To go beyond this rate in any agricultural process or development that affects the lives of a substantial proportion of the population is, I believe, to court disaster. It is hoped that the book may be of help on the agricultural side to all those concerned with making the Sudan a better place to live in.

CHAPTER II

THE HISTORICAL BACKGROUND OF SUDAN AGRICULTURE

By A. J. ARKELL, M.B.E., M.C., 4 N., B.LITT., F.S.A.
Commissioner for Archaeology and Anthropology

MAN of the Old Stone Age did not cultivate, either in the Sudan or anywhere else. He was a hunter, and for many thousand years he made stone tools, which are all that is left to-day of him and his handiwork. These tools were no doubt used by man for cutting up and skinning the animals which he hunted. In favoured localities animal bones that he had broken up for marrow may be found with his tools, but it is only comparatively late in the period that any evidence of his use of fire has been found.[1] He may have used some of his stone tools for digging up roots, as baboons on the Dinder dig up roots to-day in a year when the fruits of the forest and grass seed are not plentiful. In fact it is probable that he did so; and it is as certain as may be that his women collected berries and nuts from trees, and seed from grasses too, but there is no evidence or reason for thinking that man cultivated any of these plants or trees. Still, it is of interest to the agriculturist to note that even then man may have begun to acquire a certain knowledge of plants, and localities in which different kinds are likely to be found; and the more intelligent men and women may have realized that the two most important factors affecting the distribution of plants were the soil and the weather. Indeed, to-day in northern Darfur the Zaghawa women still collect for food the seeds of the wild grasses 'koreib' or 'umm asabi' and 'heskanīt'.

Study of the tools of Stone Age man and the various strata of the surface soil in which they are found (which is the only way of dating them) will in any case benefit the Sudan agriculturist, for it will lead him to understand much about the nature of the different soils, showing him the conditions under which the soils were formed, and the relative age of each.

It is possible to make little more than this promise in this chapter, for only in 1933 Sandford and W. J. Arkell, who made an extensive study of the Stone Age in the Nile Valley, suggested that possibly there was no Stone Age in the Sudan: no implements had then been found south of Wadi Halfa, and it seemed to them that even in the early Stone Age the desert between Wadi Halfa and Abu Hamed might have formed a barrier to man's advance. We know more than that now, but light is only just beginning to shine. Stone implements of different types have been found on the surface in many parts of the northern Sudan, and we know from studies that have been made in the neighbouring territories of Kenya and Uganda and Egypt and Palestine that the same types of implements in those territories are associated with various periods which are seen to have been times when the rainfall was alternately more than the present

[1] 'L'Acneuléen supérieur d'Oum Qatafa' (in Palestine), by R. Neuville, *Anthropologie*, xli, p. 21.

(pluvial periods) and then again less than the present (dry periods). There is even some reason for thinking that the causes for these periods may have been world-wide; and that the same causes that brought the ice southwards over Europe caused a contemporary pluvial period in central Africa. So that there is reason to think that when the evidence has all been collected in the Sudan, we shall find that we had similar climatic oscillations to those of Kenya. Traces of human occupation in the Libyan Desert make it quite clear that there have been times when the climate there was wetter than it is now; and the 'qōz' or sand-dune country of Kordofan shows clearly that it has been drier there than it is at present; between Nahud and Umm Keddada was once desert with dunes advancing from the north as they do in Dongola district to-day. Now these Kordofan dunes are anchored by vegetation watered by the rains of to-day.

My recent discovery of Chellean and Acheulean tools *in situ* in the gravel of the Khor Abu Anga at Omdurman and in two other west-bank tributaries of the Nile between Omdurman and the Sabaloka shows that Chellean man was living on an eroded surface of the Nubian sandstone only a few metres above present high Nile, and that Acheulean man who followed him was living on very much the same level, while gravel formed from the ironstone capping the Nubian sandstone was being deposited over the tools he dropped, the average deposit of such gravel being only about a metre or so deep. The discovery of these tools at once made clear to the geologist the true nature of this gravel, and showed him that it was not, as was previously thought, formed under the peculiar hot damp tropical conditions described as lateritic. Thus the discovery threw light on the past climate of the Khartoum area, and indeed it seems to have done more, for it indicates that the Sabaloka gorge must have been cut down to more or less its present depth in Acheulean times, anything up to half a million years ago; and this renders improbable Ball's hypothesis that the Gezira plain was formed by a late Palaeolithic lake that built itself up behind the Sabaloka cataract drained only by the river bursting through about 10,000 B.C.

The study of the Stone Age can no doubt throw much light on the history of the Nile and on the origin of the Gezira soil and similar problems.

Indeed I recently found late Acheulean implements on the edge of a depression which runs more or less due north, at a height of perhaps 100 ft. above present high Nile, from the bend which the Nile makes eastward near Abri to run through the Batn el Hagar to Wadi Halfa. This combined with the apparent absence of Chellean and Acheulean tools in the Batn el Hagar indicates to me that it was near the end of the Acheulean period that the Nile probably changed its course at Abri. Perhaps geologists will one day prove that that change was due to earth movements and faulting, of which I have seen apparent traces a little farther east in the Geddi area; and if so, perhaps it will be established that these earth movements took place at the time when there were considerable earth movements going on in Kenya, between the Kamasian and the Gamblian wet periods.

I have recently, too, had the opportunity to spend a few days looking for implements associated with the Singa proto-Bushman skull, the only fossil remains of man that have so far been found in the Sudan. The skull must originally have come from a fossiliferous layer of calcareous gravel which is overlain by a thick bed of clay which appears to be of the same consistency throughout, although its colour varies from red-brown above the gravel through dark greenish-grey to the typical black cracking clay soil on the surface. I found no artefacts at Singa definitely in this layer, which has been much denuded for road metal for the town; but in what is probably the same layer about 30 miles upstream at Abu Hugar and just downstream of Launi reserved forest, I found a number of artefacts and lumps of red ochre *in situ* in this gravel and other stone tools which had certainly weathered out of it; and this discovery leads me to think that we have here an assembly of artefacts not dissimilar to the culture in Kenya first called Nanyukian by Leakey and now known as Kenya Fauresmith, and which is dated to the closing phases of the Kamasian wet period. This date would fit in very well with the position of the artefacts at the top of gravel which must have been laid down by a swollen Blue Nile, swollen by the rains presumably of the Kamasian pluvial. This indicates that the clay above it, the top of which apparently forms the cotton-growing soil of the Gezira plain, was probably all laid down during the only considerable subsequent wet period known, that called the Gamblian in Kenya. But whether this hypothesis is correct or not, I think I have said enough to show that the very little study that it has been possible to give to the Stone Age of the Sudan during World War No. 2 has already thrown valuable light on the history of surface features of the Sudan, and that further study is bound to throw more light which will one day give the Sudan agriculturist a more or less clear view of the soils and water-supply of the Sudan during the time that man has been in existence, and this may be anything up to a million years.

Some time after the close of the Gamblian wet period, during which man was getting more control over the material of his stone tools (which were therefore becoming both smaller and more varied), at a date which we cannot give until careful archaeological excavations of certain key sites have been carried out, there came into the Sudan people who could make pottery, and who cultivated grain and ground it. There is no reason to think that either of these discoveries was made in the Sudan. It has usually been assumed that this civilization first reached the Nile Valley in the vicinity of Luxor from Asia via the Red Sea and the Wadi Hammamat, and this may have been the case, but we cannot be sure until more work has been done in the Sudan. Crude pottery has been found in Kenya associated with stone implements to which at present Leakey assigns a date of ?10,000 B.C., which is considerably earlier than any pottery from Egypt that it has been possible to date. Even if pottery was invented in Asia, it may have come to Kenya first, for there is reason to think that the predynastic immigrants who brought civilization to Egypt had sea-going boats, and so it is not impossible that they reached the coast of East Africa before making their way inland to the Nile via Wadi Hammamat. Also there was a tradition in Egypt that Punt (which at

different times seems to have included Somaliland, Kenya, and Southern Arabia) was the land of the gods from which the Egyptians had once come.

We must keep an open mind for the present. There are certainly a number of occupation or village sites round the junction of the two Niles, where several interesting kinds of stone implement and several advanced kinds of pottery may be found, which may only date from the dynastic period in Egypt, but which may one day be found to have been occupied at the same time and even indeed before the period known as predynastic in Egypt. (This predynastic period came to an end about 3,500 B.C.) And it is not only round the junction of the two Niles that such sites may be found.[1]

Domesticated animals (cattle, sheep, and goats) almost certainly were first brought into the Sudan from Asia (see Ch. III), although the donkey may possibly have been domesticated locally, but whether these animals were introduced by the same people who first cultivated grain in the Sudan, or whether then as now there was a clash of interests between the nomad pastoralist with his herds and the sedentary cultivator, we do not yet know; although certain rock-pictures give us the impression that the early herdsman was probably a nomad. The earliest rock-pictures of all in the Sudan represent in a more or less life-like manner the wild animals in which man was interested, because he presumably still depended on them for a livelihood. In fact the first Sudan artists must have been hunters—perhaps the descendants of the proto-Bushmen of Singa, who obviously used much red ochre, primarily presumably for the magic treatment of their own bodies, as still used in the Nuba Mountains to-day; but they may have taken to using it as a crayon; and indeed Bushmen draw artistic pictures of the chase, which are closely paralleled by pictures from the Libyan Desert and Spain that may have been the work of these ancestral Bushmen.

The pictures containing cattle seem to be later than these pictures of wild animals. Some of the cattle pictures can be proved to have belonged to the northern Sudan Nubians of about 2000–1500 B.C. who seem to have been at least semi-sedentary, but others are probably earlier and from their position probably the work of nomads.

Archaeological excavation, which alone can give us definite information about the history of the past, is as yet in its infancy in the Sudan. The earliest site that has been excavated so far is that of a village and cemetery dating from protodynastic times (*c.* 3500–3000 B.C.) on the left bank of a disused channel of the Nile at Faras near the Egyptian frontier.[2] The inhabitants used pottery and copper implements imported from Egypt, but they also made a very fine pottery ware of their own; and during the second world war a trench dug near the Omdurman bridge exposed a

[1] I think Lucas is too definite in his conclusion that Egypt derived no domestic animals or plants from the Sudan. Excavation may establish that there was a neolithic civilization in the Sudan which contributed one of the strains in Egyptian predynastic civilization; although, of course, during the dynastic period Egypt was ahead of the Sudan—except in the 25th dynasty (the evidence for the Libyan origin of which is incidentally very slight).

[2] See *Liverpool Annals of Archaeology and Anthropology*, viii, pp. 4 ff. *Oxford Excavations in Nubia*, by F. Ll. Griffith.

grave containing a number of pots, one of which is indistinguishable in shape and fabric from some of the Faras local pots; and at Omdurman this grave appears to be later than at least one and possibly two occupation layers containing advanced pottery. A number of such occupation sites are to be found around the junction of the two Niles some metres above present high Nile, although when occupied they were presumably only just above high Nile.

Although very much is yet to be learned about these occupation sites, it is interesting to note that both at Khartoum and at Faras the Nile was then considerably higher than it is to-day; and at Khartoum the presence of many complete shells of *Limicolaria flammata* Cail. and the seeds of the 'mahagaya' tree (*Celtis integrifolia* Lam.) in these sites seems to indicate that the rainfall at the time they were occupied was higher than it is to-day.

At Khartoum with one of these early pottery cultures is found a very peculiar stone implement, the like of which has so far only been recorded from the Fayum, where it is part of the Neolithic B culture of the Fayum, to which is attributed a date of somewhere about 4000 B.C.[1] This so-called gouge is so elaborate that independent invention is out of the question, but whether the Khartoum gouges are contemporary with those from the Fayum or very much later survivals only future excavation can reveal. It should be noted that in the Nuba Mountains to-day spherical stone mace-heads are still made and used that are almost indistinguishable from mace-heads of predynastic date in Egypt.

The remaining history of the Sudan must be briefly told. As far as it has been worked out it shows a Nile sinking progressively lower in its bed from 3000 B.C. to A.D. 500, since when it seems to have undergone little change. Whether the volume of the Nile shrank during this period or whether it has only deepened its bed, the archaeological record does not yet show.

During the Old Kingdom of Egypt (*c.* 3500–2500 B.C.) little is known of the history of the Sudan, except that raids or punitive expeditions were made. In the record of one such raid made by Seneferu (*c.* 2900 B.C.), the predecessor of Cheops who built the great Pyramid of Giza, it is stated that 70,000 Nubians and 200,000 cattle and small cattle (sheep and goats) were captured; and there are records of expeditions against Wawat (?Wadi Halfa district), Arerthet, Meja (?*cp.* modern Beja), and Yam (possibly the Western Sudan); and the fragments of alabaster cups inscribed with the name of Pepi I[2] (*c.* 2600 B.C.) found at Kerma were no doubt brought there by one of the many Egyptian trading expeditions of which there are records during the period, and the object of which was to obtain from the Sudan in return for Egyptian products, slaves, gold, ivory, ebony, ostrich feathers, leopard-skins, resins, myrrh, &c.

When Egypt after 400 years of anarchy began to become powerful again during the Middle Kingdom (*c.* 2000–1800 B.C.) it soon began to take an interest in the Sudan. We can read on a rock near Korosko that 'in the 29th year of Amenemhat I they came to overthrow Wawat', and this Pharaoh it probably was who founded the fortified trading-post at

[1] G. Caton-Thompson and E. W. Gardner, *The Desert Fayum*, pp. 2, &c.
[2] G. Reisner, *Harvard African Studies*, vi, p. 541, &c.

Kerma on the Dongola reach, now known as the western Defufa, and called in ancient times 'the Walls of Amenemhat'. Here resided an Egyptian governor-general of whom the first and most famous was Hepzefa, and here sprang up an Egypto-Nubian culture due to the reactions of the imported Egyptian craftsmen to existing local industries and local needs.

Judging from the position of the Dynasty XII remains at Kerma, it looks as if the land recently irrigated by the Borgeig pump scheme coincides approximately with an old channel of the Nile which was probably already silting up 4,000 years ago, although it was then still flooded and cultivated at that time, for only in its highest parts does it show any signs of contemporary human occupation; whereas much of the land between the eastern Defufa and the Wadi Khowi was occupied by squatters. To protect communication between Aswan and Kerma from interference by raiders from the desert on either side of the Nile route, a line of twelve forts were constructed, at one of which (Semna) records of the height of the Nile flood were kept during three reigns (Dyn. XII–XIII). These records show that at Semna at this time the high Nile was at least 26 ft. higher than it is to-day, and that these were true records is shown by the existence of stone walls built to catch the river silt, such as are now built between high and low Nile. These early silt-retaining walls may be seen at Semna far above present high Nile.

There was an influx from the western steppes about this time of some new-comers, probably attracted by the newly established security. These people probably did not exterminate the old inhabitants, but they made very distinctive pottery, which now appears on the Nile for the first time. Their settlements may be found on the Nile all the way from Aswan to Sai Island, and probably will be found farther south; and their pottery and grindstones have been found in the southern Libyan desert between Lagiya and Merga, between Merga and Bir Natrun, along the Wadi Howar, and near Jebel Tegeru. Pottery, from its breakable nature, is of little use to the nomad, and its discovery (with stones used for grinding either grain or grass seed) in these places now too dry for permanent human habitation indicates before 2000 B.C. a phase of somewhat higher rainfall than the present. Indeed it is not unlikely that incipient desiccation about 2000 B.C. caused these people to leave their western homes, and while some moved north-east to the Nile, where they seem to have had settlements and herds of cattle that would have needed pasture more abundant than what is found in that area to-day, others moved south-west and south to Dar Tama and Kordofan, where pottery like the C-group pottery is still made to-day. 'C-group' is the name given to these people by archaeologists for want of a better. They were a pastoral people, showing considerable love of cattle; but not only their pottery but their large and numerous cemeteries show that they were comparatively sedentary. They lived in houses of the *rakuba* type, composed of grass mats over a wooden frame.

Kerma and the forts were all burned and sacked during the dominion of Egypt by the Hyksos, the Semitic invaders who introduced the horse and the wheeled vehicle to Africa.

About 50 years after this destruction of the forts, what is now the

Northern Province of the Sudan was reconquered by the Pharaohs of the New Kingdom, as soon as they had driven the Hyksos out of Egypt. During this period the area downstream of Abu Hamad seems to have been incorporated in Egypt. Ahmes I (1580–1559 B.C.) built the smaller temple at Buhen near Wadi Halfa, and his successor Thothmes I after several campaigns extended his frontier to Kurgus, about 25 miles south of Abu Hamad, where on a rock beside the railway the boundary inscription he set up may still be read, and close by are the remains of a fort, which presumably he built to guard the river route and the road overland to Korosko.

Other temples were built at Buhen (Hatshepsut, 1501–1479 B.C.), Solb (Amenhotep III, 1412–1376 B.C.), Sesibi (Amenhotep IV), Faras, and Kawa near Dongola (Tutankhamun), and Amara West (Seti I). Between 1200 and 1100 B.C. the empire of Egypt gradually disintegrated; and little is known of the history of the Sudan, until in the eighth century B.C. at Napata near Merowe there sprang up a dynasty of uncertain origin, perhaps Sudanese tutored by the colony of Egyptian priests of Amon resident at Jebel Barkal near Kareima, who conquered Egypt.

Piankhi, renowned as a great lover of horses, completed the conquest of Egypt, and it is probable from finds at Kosti, Sennar, and Jebel Moya that his successor Shabaka was in effective control of the Sudan at least as far south as the Sennar–Kosti line, if not as far as Roseires and Malakal. Shabaka, however, came into contact with the rising power of Assyria on the borders of Palestine, and he and Tirhaka (689–664 B.C.) were defeated by the better disciplined Assyrians, who were armed with the new weapons of iron; and Tirhaka's successor Tanutamon was soon afterwards finally expelled from Egypt.

From the rise of this dynasty with its capital at Napata there had been a kind of southern capital at Meroe near Kabushia in Shendi district, governed by a cadet of the royal house.

In the fourth century B.C. Meroe became the main capital of the Sudan. Separated from Egypt, which had fallen under a succession of foreign powers, the centre of gravity of the Sudanese kingdom was nearer Meroe than Napata. Meroe was closer to the rainlands of the south. Evidence of the importance of these rainlands is provided by the numerous hafirs which stretch south of Meroe, and are particularly thick in the area south of the Sennar–Jebel Moya line. Few of these hafirs fill to-day, but they would all fill if at the end of the rains the soil in and in front of them was puddled by human feet, so concentrating it and preventing the rain-water of the following year from soaking into the ground instead of running into the hafir. It is not yet certain but it is probable that most of these hafirs date from the great periods of the Meroitic kingdom, when there were plenty of prisoners of war available for the construction of public works such as these. It is even possible that they and the move of the capital from Napata (Merowe) to Meroe (near Shendi) may have been connected with a phase of decreasing rainfall that is thought by some authorities to have begun in the Mediterranean area about A.D. 200 and to have culminated in the drought in Arabia that was one of the causes for the emigration of the Arabs in the seventh century.

During this period the camel was introduced to Africa as a transport animal (see Ch. III), and there is a little reason for thinking that the camel-carrying trade was in the hands of the Tuareg, for of course the Arabs had not yet arrived. During the prosperous periods, in addition to trade with the Mediterranean via Egypt, there seems to have been a considerable east–west trade across Africa, products of Nigeria and the western Sudan coming via Darfur, and of India and Arabia via Axum.

When the kingdom of Meroe was destroyed in A.D. 350 by an expedition from Axum, an inscription by the King of Axum referring to the event mentions the destruction of the cotton trees, presumably plants grown from seed probably obtained in the first place from India.[1]

Even before the capital was moved to Meroe, Greek traders had reached the Sudan. Some of their wares were found at Meroe when it was excavated in 1909–14, and Homer knew from them of the annual migration of the storks to central Africa, which he mentions as the unceasing war between the Cranes and the Pygmies.

Iron was first worked in the Sudan at Meroe. Indeed it is probable that it was through Meroe that iron-working came to Africa.

The 'sāqiya' water-wheel (a Persian invention) reached the Sudan during this period; and there are indications that it was extensively used for cultivating certain areas, for instance Letti Basin and part of the Wadi Ḳhowi in Dongola. Meroitic 'sāqiya' wells are usually lined with red brick, which first came into general use during this period. At least one of these 'sāqiya' wells has been brought back into use recently, but it had to be deepened by a few feet.

When Meroe was founded from Napata its civilization was entirely Egyptian in form and spirit, but it subsequently felt the successive influences of Hellenistic and Roman Egypt.

There is some reason for thinking that the sack of Meroe led to the migration of the Meroitic royal family westwards to northern Kordofan and Darfur. Civilization in the Nile Valley was not entirely extinguished during the two centuries that followed the fall of Meroe; but the art of writing seems to have been lost, and *objets d'art* show the influence of both Christianity and ancient Egypt. There was clearly considerable trade with Byzantine Egypt; but Christianity did not reach the Sudan until about A.D. 548.

During the Christian period there were two kingdoms in the Northern Sudan, with capitals at Old Dongola and Soba, a few miles up the Blue Nile above Khartoum.

In A.D. 652 the Arabs invaded Dongola from Egypt, and obtained from the King of Dongola the payment of a tribute of slaves and permission to construct a mosque there.

This state of affairs seems to have existed for about six hundred years; and then friction arose between the Moslems of Egypt and the kingdom of Dongola. To this period no doubt date the ruins of the stone-built castles of the Northern Province that show the influence of the Crusaders, and may be found surrounding the remains of small red-brick churches.

[1] More details of the history of cotton in the Sudan are given on p. 324.—*Editor.*

The church at Old Dongola is a building intended for defence, and no doubt dates from this period.

About 1340 the Christian kingdom of Dongola came to an end, and it is probable that its fall was followed by a considerable immigration of Arab tribes into the Sudan, from the west, as well as from the east, and perhaps along the Nile.

About this period the kingdom of Bornu in eastern Nigeria, which had obtained fire-arms from Tunis before the British Army had any, was becoming very powerful; and there is evidence that it controlled the desert trade routes as far as Selima. It probably at one time included Darfur as an outlying province of its empire; and the fact that the Islam of the Sudan is of the Maliki persuasion, as in Spain and the western Sudan, and not Hanifi as in Egypt, is a fairly clear indication that Islam came to the Sudan from the west.

There was probably considerable coming and going along the great east–west road between the desert and the forest at this period. The kingdom of Darfur probably arose when the hold of Bornu over its empire grew weak; and there is some reason to think that the Fung dynasty which founded the kingdom of Sennar early in the sixteenth century may have been a cadet branch of the Bornu royal family expelled from Bornu after a period of civil war.

The southern Christian kingdom of Soba, of which we know very little, and which was replaced by Sennar, was dying from lack of cultural inspiration from outside when we last hear of it, sending an unsuccessful embassy to Abyssinia in an endeavour to obtain priests to instruct the people.

The Fung Kingdom at its prime included most of the present Sudan, from Hannek in the north to Beni Shangul and the Shilluk country in the south, and from Kordofan in the west to the confines of Suakin in the east; but by the time Bruce visited Sennar early in the reign of George III it was beginning to decline. It is interesting to read in Bruce[1] of the fine horses of Sennar, whereas now there are hardly any horses in that area. The King of Sennar obtained his horses from Dongola, where also the breed has died out.

With the occupation of the Sudan in 1820 by the Turks, who found the Fung kingdom on its last legs, we reach modern history, and it only remains to mention two of their agricultural innovations which failed either during or before the Mahdia, the cultivation of cotton on a commercial scale in Sennar district, and of indigo in various localities. The ruins of one of their indigo factories may still be seen at Merowe East, and another on the west bank opposite Shendi.

[1] *Travels to Discover the Source of the Nile*, 2nd edition, vol. vi, pp. 352 A, 423, 429–30.

CHRONOLOGICAL TABLE

	Token dates only.
	B.C.
The first appearance of man	1,000,000–500,000
Man making crude pebble-tools of pre-Chellean type on the banks of a Nile 150 ft. higher than at present in the Halfa and Dongola districts.	250,000
Man making slightly less crude stone tools of Chellean type	150,000
Man making finished stone tools of Acheulean type	75,000
Early Bushman living on Blue Nile (Singa). The Nile enters the Batn el Hagar?	50,000
The Gezira cotton soil forming (?)	50,000–20,000
Sebilian silt deposited between Wadi Halfa and Kom Ombo	12,000
The first domesticated cattle in N. Africa?	8,000
Potters and cultivators reach Africa ?from Asia	5,000

	Dates approximately correct.
	B.C.
Protodynastic settlement at Faras	3200
Old Kingdom Egyptians raid Nubia	2800
Old Kingdom Egyptian trading expeditions reach Dongola	2400
Middle Kingdom Egyptians colonize Halfa and Dongola districts, with governor-general at Kerma.	2000
The Nile at Semna 26 ft. higher than to-day	1750
The Hyksos invade Egypt and introduce the horse	1700
Kerma and other Middle Kingdom forts destroyed	1650
Ahmes I expels the Hyksos and builds a temple at Buhen	1580
Thothmes I completes the occupation of the northern Sudan.	1520
Hatshepsut builds a temple at Buhen	1490
Amenhotep III builds temples at Sulb and Sadenga	1400
Amenhotep IV builds a temple at Sesibi	1380
Tutankhamun builds temples at Faras and Kawa	1350
Rameses II builds the temples at Abu Simbel	1250
Egypt has lost all its empire except the northern Sudan	1100
Kashta commences the conquest of Egypt	750
Piankhi completes the conquest of Egypt	720
Tirhaka, King of the Sudan and Egypt	688–663
Tanutamon loses Egypt to the Assyrians	660
The capital transferred from Napata to Meroe. Iron-working begins in the Sudan. The 'sāqiya' water-wheel introduced. Building in red brick becomes common.	300
The camel introduced as a baggage animal	20
	A.D.
A Roman centurion explored as far as the Sudd	60
Meroe is sacked by the King of Axum	350
Christian missionaries reach the northern Sudan	548
Dongola pays tribute to the invading Arabs	652
The King of Kanem controls the trade route from Darfur to Egypt via Selima.	1240
The Christian kingdom of Dongola falls to the Moslems from Egypt. An increased influx of Arabs into the Sudan.	1340
The Christian kingdom of Soba fails to obtain priests from Abyssinia.	1490
The Fung kindom of Sennar founded	1500
Darfur possibly a province of the Bornu empire	1535–1600
The Fur sultanate of Darfur founded	1603
The end of Fung kingdom. Khartoum founded	1820
The fall of Khartoum and death of Gordon	1885
The Battle of Omdurman	1898

CHAPTER III

SOME EGYPTIAN CONNEXIONS WITH SUDAN AGRICULTURE

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THAT various domestic animals and plants of the Sudan, which are not modern introductions into the country but which have been there for a long period, were known in ancient Egypt is certain, and theoretically this might be due to any one of three causes: first, that they are African species common to both countries; second, that the Sudan derived them from Egypt; or, third, that Egypt derived them from the Sudan.

The third solution of the problem may be dismissed at once, since it can be shown (*a*) that Egypt was civilized long before the Sudan; (*b*) that, as early as about 2000 B.C., Egypt conquered the northern Sudan and administered it for a period of about 300 years, during which time there were Egyptian settlements and garrison towns in the country; that, later, about 1580 B.C. to 1100 B.C., the northern Sudan formed an integral part of the Egyptian Empire, and that, still later, from about 750 B.C. to about 300 B.C., an Ethiopian dynasty, thought to have been of Libyan origin, ruled the northern Sudan; and (*c*) that civilization, both in Egypt and in the Sudan, has always proceeded from north to south.

Only two possibilities, therefore, remain, and before deciding between them it is necessary to determine what domesticated animals and plants, well established in the Sudan, were known anciently in Egypt, which will now be done.

The evidence is of two kinds, namely, first, illustrations on monuments and, second, remains found buried, but no attempt will be made to enumerate all the examples that exist, a sufficient number only being given to prove the statements made.

Taking the animals and plants in alphabetical order, the most important are:

Animals: Cattle, donkey, goat, horse, and sheep.

Plants: Cereals, date palm, flax, grapes, lentils, melons and vegetables.

These will now be considered separately.

ANIMALS

Cattle

The ancient Egyptian cattle were of three main types, long-horned (generally lyre-shaped horns, never lateral), short-horned, and humped.

The long-horned cattle of the Bahr-el-Ghazal and Upper Nile regions of the Sudan are undoubtedly descendants, though not necessarily pure descendants, of the long-horned wild cattle (*Bos africanus*) of Africa. These were domesticated by the Egyptians at a very early date, and are frequently shown on tomb walls, the principal examples, taking them in

date order, being Fifth Dynasty[1] (2750 to 2625 B.C.); Sixth Dynasty[2] (2625 to 2475 B.C.); Twelfth Dynasty[3] (2000 to 1788 B.C.), and Eighteenth Dynasty[4] (1580 to 1350 B.C.). Remains of these cattle have also been found buried, the date in one case being Nineteenth Dynasty[5] (1350 to 1205 B.C.), and in other instances unfortunately not being known, though probably Ptolemaic (332 to 30 B.C.).[6]

As some indication that long-horned cattle did reach the Sudan from Egypt is the presence in the Sudan to-day among the Dinkas of a peculiar and very characteristic deformation of one horn of the bull that is the leader of the herd, the horn, which is always the left one, being artificially trained downwards and forward.[7] In ancient Egypt a similar deformation was practised, the horn treated, however, not always being the left, but sometimes the right. This is depicted in a number of tombs, three of the Fifth Dynasty[8] (2750 to 2625 B.C.); one of the Sixth Dynasty[9] (2625 to 2475 B.C.) and one of the Twelfth Dynasty[10] (2000 to 1788 B.C.).

Breasted states that 'It is totally gratuitous to identify any longer the long-horned cattle of Egypt with an Asiatic species'.[11]

Lortet and Gaillard say 'Il n'y a aucune raison de croire que ce *Bos africanus* ne soit pas originaire d'Afrique où il se rencontre par milliards'.[12]

Curson and Thornton state[13]: 'it is believed that the first cattle to be

[1] G. Steindorff, 'Das Grab des Ti', pls. 12, 112, 118, 124, 125, 128, 129; N. de G. Davies, 'The Mastaba of Ptahhetep and Akhethetep at Saqqarah', i, pls. III, XXI, XXVII, XXVIII; ii, pls. III, VIII, XIV, XXI, XXII; Lepsius, *Denkmäler*, ii, pl. 70, 'The Tomb of Ma'nefer'; A. E. P. Weigall and F. W. von Bissing, 'Die Mastaba des Gen-Ni-Kai', i, pl. XI.

[2] N. de G. Davies, 'The Rock Tombs of Sheikh Said', pls. XVI, XIX, XX; A. M. Blackman, 'The Rock Tombs of Meir', iv, pls. XIV, XVI, XXIV; N. de G. Davies, 'The Rock Tombs of Deir el Gebrawi', i, pls. VII, XI; ii, pls. IV, VI, XII; P. Duell and others, 'The Mastaba of Mereruka', i, pls. 20, 21; ii, 152, 153.

[3] A. M. Blackman, 'The Rock Tombs of Meir', i, pls. IV, IX, X, XI, XX, XXVI; ii, pls. III, VI, VII, XII, XV, XXX; iii, pl. IV; N. de G. Davies, 'The Tomb of Antefoker and His Wife Senet', pls. III, V, XIII, XXII, XXIV; P. E. Newberry, 'El Bersheh', i, pls. XII, XVII, XVIII; ii, pls. V, VIII, XIV; P. E. Newberry, 'Beni Hasan', i, pls. XIII, XVII, XVIII, XXIX, XXX, XXXV; ii, pls. IV, VII, XII, XVII, XXXI.

[4] N. de G. Davies, 'The Tombs of Two Officials of Tuthmosis the Fourth', pls. XXXI, XXXII; N. de G. Davies, 'The Tombs of Menkheperrasonb, Amenmose and Another', pl. xiv; N. de G. Davies, 'The Tomb of Kenamun at Thebes', pls. XXXIII, XXXIV; Nina de G. Davies and A. H. Gardiner, 'The Tomb of Amenemhet', pls. VI A, XX; Nina de G. Davies and A. H. Gardiner, 'The Tomb of Huy', pls. VIII, XXXIII.

[5] L. Loat, 'Gurob', p. 3.

[6] Gaillard et Daressy, 'La Faune momifiée de l'antique Égypte'; Lortet et Gaillard, 'La Faune momifiée de l'ancienne Égypte'.

[7] Sir Arthur E. Shipley, *Cambridge Cameos*, London, 1924, pp. 64–88. My attention was directed to this subject by Archdeacon Shaw of the southern Sudan.

[8] G. Steindorff, op. cit., pl. 129; Lepsius, *Denkmäler*, ii, pl. 70, 'The Tomb of Ma'nefer'; N. de G. Davies, 'The Mastaba of Ptahhetep and Akhethetep at Saqqarah', i, pls. III, XXI.

[9] A. E. P. Weigall and F. W. von Bissing, op. cit., i, pl. XI.

[10] A. M. Blackman, 'The Rock Tombs of Meir', i, pls. IX, X.

[11] J. H. Breasted, 'The Origins of Civilization', *The Scientific Monthly*, 1919–20.

[12] Lortet et Gaillard, 'La Faune momifiée de l'ancienne Égypte', i, p. 70.

[13] H. H. Curson and R. W. Thornton, *Onderstepoort Journal of Vet. Sci. and Animal Industry*, vol. vii, No. 2, Oct. 1936.

domesticated in Africa were the giant horned wild oxen of the Nile Valley called by Hilzheimer *Bos primigenius*, Hahni, *nova sub-species Hilzheimer*'.

If this is admitted, then since these cattle undoubtedly were domesticated by the Egyptians as early as the Fifth Dynasty, when the Sudan was as yet uncivilized, it is reasonable to suppose that the domestication of them reached the Sudan from Egypt.

Short-horned cattle (*Brachyceros*) are shown on Egyptian monuments from a very early date, possibly from the Predynastic period, since cattle represented on a slate palette of that date appear to be short-horned,[1] though they are so badly drawn that there is room for a difference of opinion. Short-horned cattle, however, are certainly depicted on tomb walls of the Fifth Dynasty[2] (2750 to 2625 B.C.); Sixth Dynasty[3] (2625 to 2475 B.C.); Twelfth Dynasty[4] (2000 to 1788 B.C.) and onwards, and their remains have also been found, probably as late as Ptolemaic times[5] (332 to 30 B.C.). Curson and Thornton state[6]: 'Then at the end of the Neolithic era, there entered lower Egypt from Asia . . . the Brachyceros or Shorthorn . . . the first invaders of Egypt brought cattle of shorthorn type, which in time displaced the Hamitic Longhorn in Lower Egypt and even during the period of the New Kingdom (1580–945 B.C.) they were dominant.' As the Sudan was not civilized until long after Egypt, and as there was continuous intercourse between the two countries, it seems reasonable to suppose that the Egyptian shorthorn cattle (originally of Asiatic origin) were introduced into the Sudan.[7]

The zebu, or humped cattle found in the Sudan to-day, are also shown on ancient Egyptian tomb walls, though, so far as can be ascertained, not until the Twelfth Dynasty (2000 to 1788 B.C.), from which time they are pictured in a number of tombs.[8] Davies states[9] that 'The humped bull . . . is no doubt of a breed imported from Syria and farther east, where the zebu still keeps the ancient characteristics. This creature is again depicted in tombs 17, 40, 343. . . . It is being imported from Syria in Tomb 162 and is mentioned in the list of imports thence. Hilzheimer remarks that the fleshy hump points to an origin in an arid region where periods of scanty provender prevailed.'

It seems probable, therefore, that the ancestors of the present-day Sudan humped cattle at first reached the Sudan through Egypt, though, much later, also probably by importation through East Africa.

[1] J. E. Quibell, *Archaic Objects*, No. 14238.

[2] G. Steindorff, 'Das Grab des Ti', pl. III.

[3] P. Duell and others, 'The Mastaba of Mereruka', pls. 24, 25, 168, 169.

[4] A. M. Blackman, 'The Rock Tombs of Meir', ii, pl. xv; iii, pl. XIII; Gaillard et Daressy, 'La Faune momifiée de l'antique Égypte', No. 29525.

[5] P. E. Newberry, 'Beni Hasan', i, pl. xxxv.

[6] H. H. Curson and R. W. Thornton, op. cit., p. 620.

[7] Mr. A. J. Arkell informs me that short-horned cattle are represented in the chapel of a pyramid at Meroe.—*Editor*.

[8] P. E. Newberry, 'Beni Hasan', i, pl. xxx; N. de G. Davies, 'The Rock Tombs of El Amarna', i, pls. XXV, XXIX; N. de G. Davies, 'The Tombs of Menkheperrasonb, Amenmose and Another', pls. XIV, XXXIV, XXXV, XXXVI, p. 13.

[9] N. de G. Davies, 'The Tombs of Menkheperrasonb, Amenmose and Another', pls. xiv, xxxiv, xxxv, xxxvi, p. 13.

Donkey

Breasted states that 'The domesticated donkey of Egypt was long ago demonstrated by Schweinfurth and others to have had its original home in north-east Africa, and to have been domesticated on the Nile. Its wild ancestor *Asinus taeniopus* . . . is still found as far north as the mountains of southern Nubia.'[1]

Anderson shows[2] that the wild donkey was, and possibly still is, found both in southern Nubia and in the northern Sudan.

The earliest representation of donkeys that is known from ancient Egypt is on a slate palette dating from the predynastic period (before 3400 B.C.),[3] where they are shown as having been captured by the Egyptians from certain people, generally identified as Libyans, though Oric Bates says of them 'to me they appear to have been Egyptians of the Delta'.[4]

From the Fifth Dynasty (2750 to 2625 B.C.), which is the earliest date at which tombs were decorated in Egypt, onwards, the donkey is frequently shown on tomb walls, examples of which may be mentioned from the Fifth,[5] Sixth,[6] and Twelfth[7] Dynasties respectively.

During the Sixth Dynasty (2625 to 2475 B.C.) a certain Egyptian in the reign of Pepi II made an expedition into Nubia taking with him various objects, which are enumerated, as presents, which it is stated were carried on one hundred donkeys.[8]

Skeletons of donkeys, however, have been found of First Dynasty date (about 3300 B.C.).[9]

It seems very probable that the donkey was first domesticated in Upper Egypt.

Goat

Peake and Fleure state that 'The goat is found wild over most parts of central, eastern, and southern Asia . . . there is no evidence that it was wild in north Africa'.[10]

Breasted states that in the middle of the twenty-eighth century B.C. there were two varieties of goat in Egypt, one of which was *Hircus mambricus*.[11] Lortet and Gaillard mention three species of goat of which remains have been found, namely *H. mambricus*, *H. thebaicus*, and *H.*

[1] J. H. Breasted, op. cit.
[2] J. Anderson, 'Zoology of Egypt, Mammalia', 1902, pp. 329–31.
[3] J. E. Quibell, 'Archaic Objects', No. 14238.
[4] Oric Bates, 'The Eastern Libyans'.
[5] G. Steindorff, op. cit., pls. 122, 124; N. de G. Davies, 'The Rock Tombs of Sheikh Said', pl. XVI; N. de G. Davies, 'The Mastaba of Ptahhetep and Akhethetep at Saqqarah', pls. VII, VIII.
[6] A. M. Blackman, 'The Rock Tombs of Meir', iv, pls. XIV, XXII; N. de G. Davies, 'The Rock Tombs of Deir el Gebrawi', i, pl. XII; ii, pl. VI; P. Duell and others, 'The Mastaba of Mereruka', ii, pls. 169, 170.
[7] A. M. Blackman, 'The Rock Tombs of Meir', ii, pl. V; P. E. Newberry, 'Beni Hasan', i, pl. XXX; ii, pls. VII, XII, XVII.
[8] J. H. Breasted, 'Ancient Records of Egypt', i.
[9] W. M. F. Petrie, 'Tarkhan II', p. 6.
[10] H. Peake and H. J. Fleure, 'Peasants and Potters', pp. 35–6.
[11] J. H. Breasted, 'The Origins of Civilization', p. 418.

reversus.[1] Goats are shown on Egyptian tomb walls from the Sixth,[2] Twelfth,[3] and Eighteenth[4] Dynasties respectively.

Since the ancestors of the present Sudan goat almost certainly originated in western Asia, it is probable that they reached the Sudan through Egypt, where there is the only land connexion between Asia and Africa.

Horse

Peake and Fleure state[5] that 'The horse . . . seems to have developed in Asia, where Przewalski's horse still runs wild', and again, 'All the available evidence indicates that the horse was first tamed in some part of the Asiatic steppe'.

There is no evidence known to me of the horse having been used in ancient Egypt before the invasion of the Hyksos from Asia, which took place not before 1780 B.C., and there is general agreement among Egyptologists that the Hyksos brought into Egypt both horses and chariots.

Horses are frequently depicted on Egyptian tomb walls of the Eighteenth Dynasty.[6]

It seems probable, therefore, that the horse reached the Sudan from Egypt.

Sheep

Hilzheimer, writing of sheep, says:[7] 'Domestication can only have occurred where the wild sheep already had its home. This at once excludes the whole of Africa, as the wild breed proper never existed there. For the maned sheep of North Africa, despite its name, is not really a sheep. . . . Europe, too, is eliminated. Asia only is left; and even here . . . we must limit ourselves to the countries lying between the Mediterranean and the Pamirs. . . .'

Two breeds of sheep were known to the ancient Egyptians, one (*Ovis longipes*) with transverse horns spirally twisted, which is shown on a slate palette of Predynastic date,[8] and in tombs of Fifth,[9] Sixth,[10] and Twelfth[11] Dynasties respectively, but which disappears from Egypt soon after the beginning of the New Empire (1580 to 1350 B.C.), being replaced by a breed (*Ovis platyura*) with horns curving downwards and forwards, which first appears in the Twelfth Dynasty[12] (2000 to 1788 B.C.).

The sheep with transverse horns spirally twisted, which is found at

[1] Lortet et Gaillard, op. cit., pp. 107–282.
[2] A. M. Blackman, 'The Rock Tombs of Meir', iv, pl. XVI.
[3] P. E. Newberry, 'Beni Hasan', i, pl. XXX.
[4] Nina de G. Davies and A. H. Gardiner, 'The Tomb of Huy', pl. XVIII.
[5] Peake and Fleure, 'Peasants and Potters', pp. 37–8.
[6] N. de G. Davies, 'The Tombs of Two Officials of Tuthmosis the Fourth', pl. VI; N. de G. Davies, 'The Tombs of Menkheperrasonb, Amenmose and Another', pls. VII, XXXV; Nina de G. Davies and A. H. Gardiner, 'The Tomb of Huy', pl. VIII.
[7] M. Hilzheimer, 'Sheep', *Antiquity*, x (1936), p. 195.
[8] J. E. Quibell, 'Archaic Objects', No. 14238.
[9] G. Steindorff, 'Das Grab des Ti', pl. III; N. de G. Davies, 'The Rock Tombs of Sheikh Said', pls. VIII, XVI.
[10] P. Duell and others, 'The Mastaba of Mereruka', ii, pl. 169.
[11] P. E. Newberry, 'El Bersheh', i, pl. XXV.
[12] P. E. Newberry, 'Beni Hasan', i, pl. XXX.

the present day among the Dinkas, Nuers, and Shilluks of the Sudan, is almost certainly a descendant of the early Egyptian sheep, and, if so, it must have reached the Sudan not later than the beginning of the New Empire, and the other sheep, with the horns curving downwards and forwards, later.

Animals not represented on the Egyptian monuments

Camel

Petrie states[1] that 'The camel seems to have been always on the borders of Egypt, appearing in the Ist, the XIXth and the XXVth dynasties, and fairly often in the Roman period as a carrier of large water-jars. When it came in as the main vehicle for heavy burdens, at the Arab invasion, it greatly altered the country by destroying the desert trees and vegetation.'

Robinson states[2] '. . . it is clear that a species of camel, possibly the dromedary, lived on the frontiers of Egypt during the pre-dynastic period and disappeared entirely from Egyptian knowledge after the third or possibly the sixth dynasty'.

Scharff in 1926 gave a list of thirteen occurrences of representations of the camel in ancient Egypt, all that were known up to that time, five of which are Graeco-Roman and two Roman, and he says that the camel was known in Egypt from about the Persian period (525 to 332 B.C.), the Egyptians having come into contact with it during war, or by commerce, with Syria and Palestine.[3]

These examples, omitting the very late ones, are (*a*) a small pottery head of First Dynasty date found by Petrie at Abydos;[4] (*b*) a terra-cotta head, also of the First Dynasty, found by Quibell at Hierakonpolis, which is described as a donkey's head,[5] but which Petrie says[6] is that of a camel; (*c*) an example of Sixth Dynasty date;[7] (*d*) a pottery figure of a camel with water-jars of the Nineteenth Dynasty found by Petrie at Gizeh-Rifeh, with reference to which he says, 'It shows that as early as Ramesside times it was sufficiently common to be used as a beast of burden';[8] (*e*) a glazed figure from the end of the New Empire, about 1000 B.C.;[7] (*f*) another example from the New Empire;[7] and (*g*) an example from about the fifth century B.C.[7]

Since Scharff wrote, however, a specimen of camel-hair rope of Old Kingdom date (2980 to 2475 B.C.) has been found by Miss Caton-Thompson in the Fayum province of Egypt, who says:[9] 'The position of this specimen . . . leaves no possible doubt of its authentic Old Kingdom age. . . . This, I believe, is the first record of the animal in early Egypt, apart from one or two dubious modelled representations of it. . . .

[1] W. M. F. Petrie, 'Social Life in Ancient Egypt', p. 139.
[2] A. E. Robinson, *Sudan Notes and Records*, xix (1936), pp. 47–69.
[3] A. Scharff, 'Das Vorgeschichtliche Gräberfeld von Abusir el-Meleq', p. 40.
[4] W. M. F. Petrie, 'Abydos', ii, pl. x (224), pp. 27, 49.
[5] J. E. Quibell and F. W. Green, 'Hierakonpolis', ii, pl. LXII.
[6] W. M. F. Petrie, 'Gizeh and Rifeh', p. 23.
[7] A. Scharff, op. cit.
[8] W. M. F. Petrie, 'Gizeh and Rifeh', pl. XXVII, p. 23.
[9] G. Caton-Thompson and E. W. Gardner, 'The Desert Fayum', pp. 88, 119, 123.

Was the camel then so common that even poor manual labourers . . . could obtain its hair for twisting into cord . . . ? Or was it imported ready-made from some camel-breeding country outside Egypt? This seems improbable. . . .'

In addition to the Egyptian evidence of the camel, there is a bronze figure of a camel with a pack saddle found by Reisner at Meroe in the Sudan[1] now in the Khartoum Museum. Addison says:[2] 'This is from the tomb of Prince Arikharer (25–15 B.C.) and is important not only because it is the earliest known figure of a camel in the round, but also because it indicates that the camel had been introduced into the country before 25 B.C.' This introduction was probably by way of Egypt.[3]

Water Buffalo (Gamoose)

The water buffalo, now so common in Egypt, does not figure on the monuments and was not known in the country anciently, being a comparatively modern importation from India. It has no connexion with the wild buffalo of Africa.

PLANTS

Cereals

(*a*) *Barley*. Barley (*Hordeum vulgare* and *H. distichum*), both grain and husks, has been found in Egypt from the Neolithic period,[4] which ended possibly about 5000 B.C. The finder states that the evidence 'points towards the Neolithic barleys being of local North African origin'. Husks of barley have also been found in the stomach contents of Egyptians of Predynastic date,[5] that is from between 5000 and 3400 B.C.

Peake, writing before the Neolithic discovery, says:[6] 'We may, therefore, rest satisfied that during what are called "predynastic times" the inhabitants of Upper Egypt used barley for food and presumably cultivated the plant.'

As Egypt was civilized long before the Sudan, barley almost certainly reached the Sudan from Egypt.

(*b*) *Wheat*. Wheat (*Triticum dicoccum*, Emmer), both grain and husks, has been found in Egypt from both the Neolithic period and also from the Predynastic period, in the latter cases from two different localities.[7]

Peake says[8] of Emmer wheat: 'This was the only kind of wheat grown in the Mediterranean region until the Roman civilization arose in Italy,

[1] G. A. Reisner, *Bulletin, Museum of Fine Arts, Boston*, xxi (1923), p. 21.

[2] F. Addison, 'A Short Guide to the Museum of Antiquities', Khartoum, 1934, p. 28.

[3] Mr. A. J. Arkell has pointed out that this small bronze figurine might have been imported.—*Editor*.

[4] G. Caton-Thompson and E. W. Gardner, 'The Desert Fayum', pp. 43, 46–50, 88.

[5] G. Elliot Smith, 'The Ancient Egyptians', 1923, p. 49; H. Peake, 'The Origins of Agriculture', 1928, pp. 34–5.

[6] H. Peake, op. cit., p. 35.

[7] G. Brunton and G. Caton-Thompson, 'The Badarian Civilization', p. 63; (*a*) T. E. Peet, 'The Cemeteries of Abydos', ii, pp. 7–13; (*b*) T. E. Peet and W. L. S. Loat, 'The Cemeteries of Abydos', iii, pp. 1–7.

[8] H. Peake, op. cit., p. 23.

and no other kind of wheat was grown in Egypt until a few years before the beginning of the Christian era.'

Watkins says[1] of Emmer wheat: 'In Egypt it was cultivated at least from the Badarian period onwards; and is the only species so far found in tombs, with the possible exception of a single sample. . . .'

Peake, summarizing the evidence regarding the country of origin of wheat, states:[2] 'This evidence seems to point definitely to the conclusion that Emmer, and other forms of wheat as well, were first cultivated in some part of Asia.'

Wheat most probably reached the Sudan from Egypt.

(*c*) *Millet.* The husks of millet have been found among the stomach contents of the Predynastic Egyptians, and Elliot Smith says of it:[3] 'The millet that was eaten by the earliest Predynastic Egyptians was . . . a species that is no longer cultivated (*Panicum colonum*).'

Peake says:[4] 'A kind of millet (*Panicum colonum*)[5] grows wild in the Sudan, and was used at an early date by the Egyptians; whether they cultivated this grain or merely collected the seeds from the wild plant is, and must remain, uncertain.'

Although I cannot find any direct evidence to prove that this early millet grew wild at that time in Egypt, it almost certainly did grow wild and may even have been cultivated, since it still is extremely unlikely that the Egyptians obtained their supplies from the Sudan, and it still grows wild in the western Mediterranean region, in the Nile Delta, in the Fayum, in the Nile valley, and in the western oases.[6]

The millet now so extensively cultivated both in Egypt and in the Sudan is a different kind of millet, *Sorghum vulgare* (*Andropogon sorghum*); Arabic name 'dura' or 'dura baladi', which is sometimes spontaneous in Egypt,[7] but whether it is also spontaneous in the Sudan is not stated. No evidence can be found to show whether this millet reached the Sudan from Egypt or not.[8]

Date Palm

Although Arabia is generally regarded as the home of the date palm (*Phoenix dactylifera* Linn.), there is no evidence for this, and it was certainly known in Egypt from a very early period and is often represented on tomb walls. A tomb of the Second or Third Dynasty (about 3000 to 2900 B.C.) at Saqqara was roofed with palm logs;[9] in a tomb of early date at Gau near Asiut;[10] in a Fourth Dynasty tomb adjoining the pyramid of Chephren at Giza and in the Fifth Dynasty tomb of Ptahhetep at Saqqarah a roof of

[1] A. E. Watkins, 'The Origin of Cultivated Plants', *Antiquity*, vii (1933), p. 75.

[2] H. Peake, op. cit., p. 42.

[3] G. Elliot Smith, 'The Ancient Egyptians', 1923, p. 49.

[4] H. Peake, 'The Origins of Agriculture', p. 20.

[5] *Panicum colonum* L. is now called *Echinochloa colona* Link, and is commonly used as a famine food in the Sudan.—*Editor.*

[6] R. Muschler, 'A Manual Flora of Egypt', 1912, i, p. 53.

[7] R. Muschler, op. cit., p. 44.

[8] In the discussion of dura in the chapter on crops it is made clear that this millet is indigenous in the Sudan.—*Editor.*

[9] J. E. Quibell, 'Excavations at Saqqara' (*1912–1914*), p. 21.

[10] Villiers Stuart, 'The Funeral Tent of an Egyptian Queen', p. 83.

this kind has been copied in stone. Also, fruit stones of a wild date (*Phoenix sylvestris* Roxb.) of early Upper Palaeolithic times have been found in a deposit of late Pleistocene age in the Kharga Oasis.[1]

Muschler states[2] that 'The Date-palm is found from the Canaries through the Sahara and Arabian deserts to south-west Asia. . . . Owing to this species having been cultivated throughout northern subtropical Africa from remote times, it is difficult to decide where it is truly indigenous.'

Flax

Flax, originally often *Linum humile* Linn., but now generally *Linum usitatissimum* Linn., has been cultivated in Egypt from a very early period, since linen fabrics have been found of Neolithic,[3] Predynastic,[4] and First Dynasty[5] dates respectively. Muschler states[6] that *L. humile* Linn. is still cultivated and often naturalized in the northern Delta of Egypt and that *L. usitatissimum* Linn. is cultivated and often semi-naturalized.

There can be little doubt that flax was introduced originally into the Sudan from Egypt.

Grapes

The wine-press hieroglyph was used in Egypt in the First Dynasty,[7] from which period wine-jars also are known, and wine, meaning grape wine, is referred to in the Third Dynasty.[8] Vintage scenes are often depicted upon tomb walls, thus, to take a few examples, in a Fifth Dynasty tomb at Saqqara,[9] in a Sixth Dynasty tomb at Saqqara,[10] in a Twelfth Dynasty tomb at El Bersheh;[11] in several tombs of the same period at Beni Hasan;[12] in many others of Eighteenth and Nineteenth Dynasty dates in the Theban necropolis, the gathering, treading, or pressing of grapes, or all three of these operations, are shown.

It seems practically certain that the cultivation of the vine reached the Sudan from Egypt.

Lentils

Lentils (*Lens esculenta* Moench) are cultivated abundantly almost everywhere in Egypt at the present time and have been cultivated for several thousands of years, but exactly when the cultivation began is not

[1] G. Caton-Thompson and E. W. Gardner, 'The Prehistoric Geography of Kharga Oasis', in *The Geographical Journal*, lxxx (1932), p. 384.

[2] R. Muschler, 'A Manual Flora of Egypt', i, p. 187.

[3] G. Caton-Thompson and E. W. Gardner, 'The Desert Fayum', p. 46.

[4] G. Brunton and G. Caton-Thompson, 'The Badarian Civilization', pp. 64–7; G. Brunton, 'Qau and Badari', i, pp. 70–1; W. M. F. Petrie, 'Prehistoric Egypt', p. 47.

[5] W. B. Emery, 'The Tomb of Hemaka', p. 43.

[6] R. Muschler, op. cit., p. 569.

[7] W. M. F. Petrie, 'Social Life in Ancient Egypt', pp. 102, 135.

[8] J. H. Breasted, 'Ancient Records of Egypt', i, 173.

[9] N. de G. Davies, 'The Mastaba of Ptahhetep and Akhethetep at Saqqarah' i, pls. XXI, XXIII.

[10] P. Duell and others, 'The Mastaba of Mereruka', pls. 113, 114, 116.

[11] P. E. Newberry, 'El Bersheh', i, pls. XXIV, XXVI, XXXI.

[12] P. E. Newberry, 'Beni Hasan', i, pls. XII, XLVI; ii, pls. VI, XVI.

known, though it was certainly long before the Sudan was civilized and, therefore, it seems most probable that the knowledge of lentils reached the Sudan from Egypt.

Pliny (first century A.D.) says that two kinds of lentils were grown in Egypt.[1]

Athenaeus (end of second and beginning of third century A.D.) writes:[2] '. . . you men of fair Alexandria . . . have been brought up on lentil food, and your entire city is full of lentil dishes.'

Schweinfurth identified 'Un morceau de pâte de lentilles cuites dont les graines se laissent facilement détacher et analyser et par cela même ne présentent pas le moindre doute sur leur détermination'.[3] The date, however, given by Schweinfurth, namely Twelfth Dynasty, Keimer says is doubtful.[4]

Newberry found a quantity of lentils among the material from the Roman cemetery of Hawara.[5]

The literature of the subject is given fully by Keimer.[6]

Melons

Under this head it will be convenient to deal with several members of the order Cucurbitaceae, namely, cucumbers, sweet melons, and water melons.

The cucumber (*Cucumis sativus* Linn.; Arabic 'khiyar') is cultivated almost everywhere in Egypt, and Muschler, who states that it is often subspontaneous, says that the country of origin is unknown.[7]

The sweet melon (*Cucumis melo* Linn.; Arabic 'shammām') is widely cultivated in Egypt and is also known from tropical Africa.[8] A quantity of melon seeds were found in the tomb of Tut-ankhamun, which are probably those of the sweet melon, though this has not been confirmed by a botanical examination.

Cucumis melo, var. *chate* (Arabic 'abd el lawry') is grown plentifully in Egypt[8] and was certainly grown anciently.[9]

The water melon (*Citrullus vulgaris* Schrad.; Arabic 'battīkh'), which is cultivated almost everywhere in Egypt, is also widely distributed in tropical Africa.[10] Although it is frequently stated to be of American origin because it is grown so plentifully there, it is probably originally from Africa, having been taken to America by the Portuguese.[11]

It seems probable that the cultivation of these plants was introduced into the Sudan from Egypt.

[1] xviii. 31.
[2] 'The Deipnosophists', iv. 158.
[3] G. Schweinfurth, *Bull. de l'Institut Égyptien*, 1884, p. 7.
[4] L. Keimer, *Bull. de l'Institut Français d'Archéologie Orientale*, xxviii, p. 80.
[5] P. E. Newberry, in 'Hawara, Biahmu and Arsinoe' (W. M. F. Petrie), 1889, p. 49.
[6] L. Keimer, op. cit., p. 81.
[7] R. Muschler, 'A Manual Flora of Egypt', ii, p. 936.
[8] R. Muschler, op. cit., ii, p. 937.
[9] L. Keimer, (*a*) op. cit., (*b*) p.92; (*b*) 'Die Gartenpflanzen im alten Ägypten', 1924, pp. 14–17, 85–6, 130–3.
[10] R. Muschler, op. cit., p. 938.
[11] O. F. White, *Nature*, cxlvii (1941), p. 802.

Vegetables

A large number of vegetables are pictured on the walls of tombs in Egypt, chiefly as food offerings, but in so conventional a manner that special Egyptological and botanical knowledge are needed to interpret them. The remains of others have been found in tombs. Some of these vegetables have been described by Dr. L. Keimer,[1] including certain kinds of beans, chick peas, peas (introduced at a very late period), lupin, and lettuce, but as I have no knowledge of the particular varieties of these vegetables grown in the Sudan, I shall not attempt to determine whether or not any of them reached the Sudan through Egypt.

Beans were known anciently from Egypt and, although Herodotus (fifth century B.C.) states[2] that 'The Egyptians sow no beans in their country; if any grow, they will not eat them either raw or cooked; the priests cannot endure even to see them, considering beans an unclean kind of pulse', they are mentioned in quantity from the time of Rameses III (1198 to 1167 B.C.),[3] as also is cabbage.[4] Athenaeus (end of second and beginning of third century A.D.) also mentions both Egyptian beans[5] and Egyptian cabbage.[6]

The Israelites, after they had left Egypt (1446 to 1440 B.C.) longed for 'the cucumbers, and the melons, and the leeks, and the onions, and the garlick' of Egypt.[7]

Plants not known in Ancient Egypt

Cotton

The home of the cotton industry is undoubtedly India, and a small piece of woven cotton fabric has been found at Mohenjo-daro in the lower Indus valley, which is dated to between 2750 and 3250 B.C.[8]

The earliest cotton fabrics that can be traced from Egypt are of the Roman period, found at Karanog in Nubia, which originally were reported as linen,[9] but which have been re-examined and are undoubtedly cotton.[10]

Cotton fabrics of Graeco-Roman date have been found at Meroe in the Sudan.[10]

[1] L. Keimer (*a*) 'Die Gartenpflanzen im alten Ägypten', 1924; (*b*) *Bull. de l'Inst. Franç. d'Archéologie Orientale*, xxviii (1929), pp. 49–97.

[2] ii. 39.

[3] J. H. Breasted, 'Ancient Records of Egypt', iv. 301, 350.

[4] J. H. Breasted, op. cit., 240, 393.

[5] 'The Deipnosophists', iii. 72, 73.

[6] Ibid., i. 34.

[7] Num. xi. 5; Mr. A. J. Arkell points out that in Darfur the onion is known in vernacular languages by the Arabic name *basl*, so that presumably it has reached Darfur only recently.—*Editor.*

[8] Sir J. Marshall, 'Mohenjo-daro and the Indus Civilization', pp. vi, 33, 194; E. Mackay, 'The Indus Civilization', pp. 103, 137–8.

[9] C. L. Woolley and D. Randall MacIver. 'Karanog, The Romano-Nubian Cemetery', pp. 27, 28, 245, pl. 108, fig. 1.

[10] F. Ll. Griffith and Mrs. G. M. Crowfoot, *Journal of Egyptian Archaeology*, xx (1934), pp. 5–12; R. E. Massey, *Sudan Notes and Records*, vi (1923), pp. 231–3. Mr. Massey, when he left the Sudan, kindly gave me his specimens and microscope slides and I was able to confirm his conclusions.

There are also two literary references to cotton fabrics in Nubia, one dated A.D. 350 and the other 1173.[1]

Reasoning from these facts, the late Professor F. Ll. Griffith says:[2] 'One must not lose sight of the possibility that the Red Sea trade, much developed in Roman times, might have introduced cotton from India to the Meroites; but the evidence is now strongly in favour of a Sudanese origin for the cotton used in Egypt and Nubia in early times.' Mrs. Crowfoot says:[3] 'On the whole it looks as if one might think that the Meroe cotton was grown in the country—and woven there, then—of course.'

Sir Harold MacMichael states:[4] 'It was also remembered that the Sudan had almost certainly been the original home of the long-stapled cotton grown in Egypt. A Frenchman named Jumel, who, in 1820, introduced cotton cultivation on a large scale into Egypt, got the first seed from a plant growing in the garden of a Turkish official . . . who had been governor of Sennar and Dongola and brought back some cotton seed with him to Cairo. So, in 1900, a little cotton was planted at Shendi as an experiment.'[5]

Interesting as the foregoing suggestions are, they are purely of academic importance, since the modern large-scale growing of cotton in the Sudan resulted from a consideration of the value of the cotton crop in Egypt and a desire on the part of the Sudan agriculturists to emulate Egypt.[6]

Fruits

Certain fruits, the guava, mango, orange, and pawpaw, now grown both in Egypt and the Sudan, are of comparatively late introduction into both countries.

The guava is a native of tropical America and the West Indies, from where it must have reached Egypt, and later, the Sudan.

The mango is a native of tropical Asia and is indigenous in India, from which country it must have been introduced into Egypt and the Sudan, probably into Egypt first. Although now grown extensively in Egypt, it is only during the last twenty years that the mango has become of any importance as a fruit crop.

[1] F. Ll. Griffith, op. cit., p. 7.

[2] Op. cit., p. 7.

[3] Op. cit., p. 12.

[4] Sir H. MacMichael, 'The Anglo-Egyptian Sudan', p. 80.

[5] Mr. A. J. Arkell writes that 'the spinning and weaving of cotton into cotton cloth seems to have reached Darfur from North Africa via West Africa and not via the Nile. Homespun cotton in Darfur is called *dandy* or *tandi*, by which name it was known in Bornu at the time of Qalqashandi. Dandy was the name of the eastern province of Songhai.

'The standard length of cotton cloth in Darfur is known as "tukiya" which must equal "shukiya" given by El Bakri as the name of strips of cotton cloth used with the Arabs as currency on the Upper Niger in the eleventh century.

'I do not see why Meroe should not have obtained cotton seed from India, for Meroe was trading with India through Axum. When Aeizanes of Axum broke up the kingdom of Meroe in A.D. 350 he mentions the destruction of the cotton.

'The Turks reintroduced cotton into the Province of Sennar about 100 years ago.' See also discussion on pp. 324 and 325.—*Editor*.

[6] The value of cotton as a cash crop was also well known in the U.S.A. and India and the local damur industry had been in existence for centuries.—*Editor*.

The original home of the orange was China and the Indo-Chinese peninsula, from where it spread to Arabia, thence to Iraq and Syria and ultimately to Africa, probably reaching Egypt first and then the Sudan.

The pawpaw is common in south-west Asia, whence it probably reached the Sudan, from where the few trees now in gardens in Cairo almost certainly were derived.

None of these fruits were known in ancient Egypt.

(*Phoenix dactylifera* Linn.) line the banks of the Nile. The 'dōm' palm (*Hyphaene thebaica* Mart.) is also common near the river where Halfa

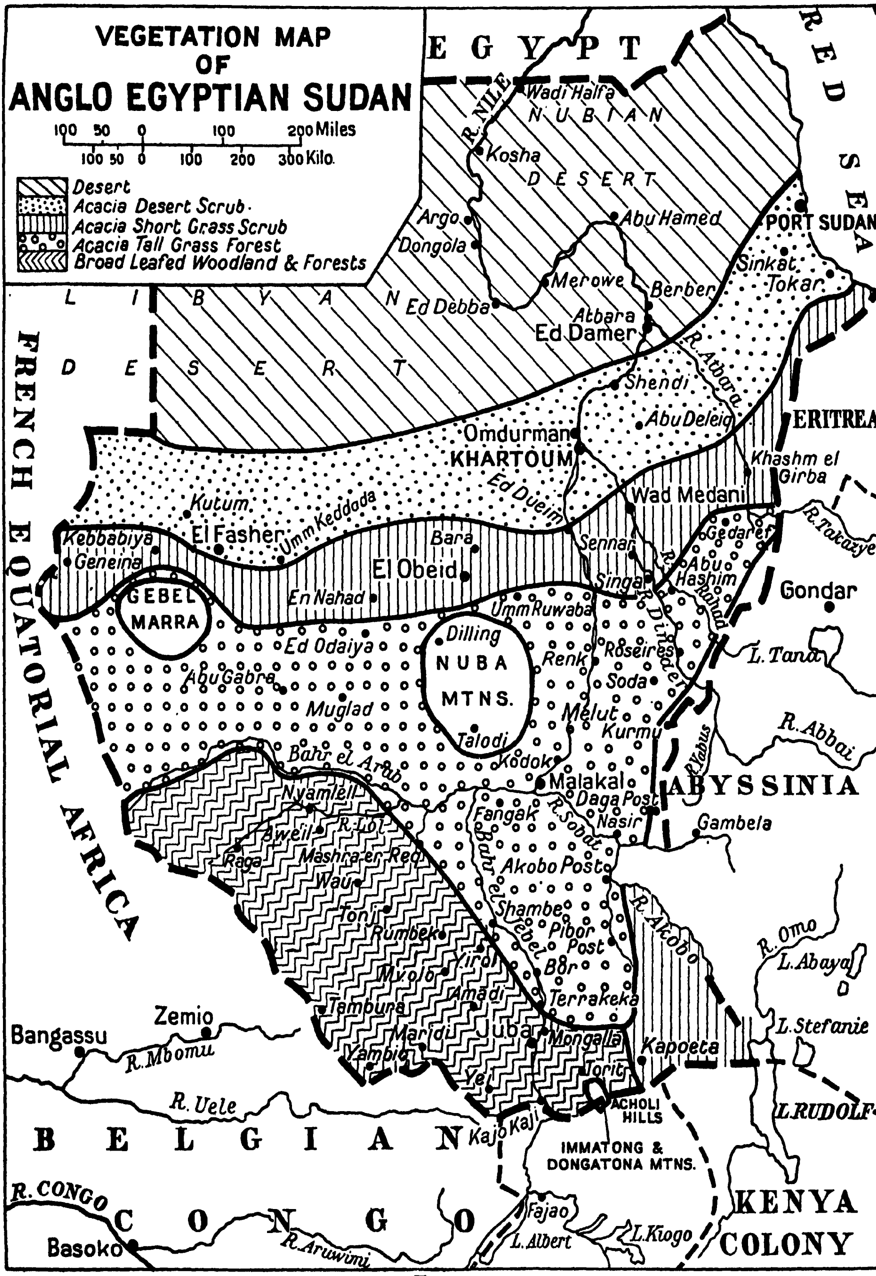


FIG. 1.

grass (*Desmostachya cynosuroides* Stapf) is abundant, and several species of *Aristida* with their three-pronged awns, and 'tumām' grass (*Panicum turgidum* Forsk.) grow sparsely in the drier situations. Along the river

FIG. 2. River Atbara: Rashaida Arabs watering their animals (*photo G. J. Fleming*).

around Dongola and southwards occur frequent trees of sunt (*Acacia arabica* Del.), the red-barked 'talh' (*Acacia seyal* Del.), the light barked 'harāz' (*Acacia albida* Del.), the largest of the Sudan acacias with its fleshy orange-coloured sinuous flat pods. Inland from the river the land is covered with shrubby 'sallam' (*Acacia flava* (Forsk.) Schweinf.), which decreases in quantity as we proceed westwards from the river.

The southern part of this region consists essentially of a plain of loose red sand with broad undulations, the vegetation where it occurs consisting principally of the bushy thorny *Fagonia cretica* Linn., the smaller *Indigofera bracteola* DC., and *Aristida papposa* Trin. & Rupr. These plants grow in patches in stretches of country without any other vegetation. The watercourses in the neighbourhood of rocky hills often contain the leafless switchlike 'marakh' (*Leptadenia spartum* Wight) and 'tumām' grass. Towards the southern boundary near the river there begins to appear a scanty growth of the flat-topped 'samr' (*Acacia tortilis* (Forsk.) Christensen), the scrubby 'sallam', associated with the leafless spiny 'tundub' (*Capparis decidua* Pax.), the thorny 'nabaq' or 'sidr' (*Ziziphus spinachristi* Willd.) with its edible fruit, 'mokhēt' (*Boscia senegalensis* (Pers.) Lam.) with its sweet-scented flowers and edible fruit, and *Cadaba farinosa* Forsk.

2. *Acacia Desert Scrub Region*

This region extends southwards to a line roughly south of Tokar to just north of Wad Medani and westwards to Dueim and Fasher. It includes Khartoum and district and the northern portion of the Gezira irrigated cotton area. It has an annual rainfall from 2 to 12 in. with a drought period of about 8 months. In this region shrubs and trees are more plentiful, the chief floristic character being the dominance of *Acacia* spp. The vegetation, however, is in general scattered and areas may occur without trees, supporting only a scanty shrubby flora. Towards the southern boundary the obconical pale-barked shrub 'la'ōt' (*Acacia orfota* (Forsk.) Schweinf.) on lighter soils, and the larger dark-barked 'kitr' (*Acacia mellifera* Benth.), with its ferocious thorns, on heavier soils are characteristic shrubs or small trees of the plains. Other common trees and shrubs are 'sidr', 'mokhēt', the ubiquitous 'heglīg' (*Balanites aegyptiaca* Del.) with its straight green spines and edible fruit, and *Cadaba farinosa* Forsk., while the tooth-brush tree (*Salvadora persica* Linn.), 'ūsher' (*Calotropis procera* Ait,) with its milky juice and large globular fruit containing a silky floss, and 'qammēz' (*Ficus sycomorus* Linn.) occur as we approach the river. In localities with clayey soil subject to inundation, sunt occurs and is replaced on the higher ground by 'harāz' and 'talh'. Of the grasses in this area, 'tumām', 'nāl' (*Cymbopogon nervatus* Chiov.), and *Schoenefeldia gracilis* Kunth. are common, with *Aristida* spp. 'haskanīt' (*Cenchrus biflorus* Roxb.) with its tiresome spiny fruits, and other short grasses on the drier land. Among climbing plants, the ubiquitous 'salāla' (*Cissus quadrangulus* Linn.) is the most conspicuous.

The eastern portion of this region contains the country of the Red Sea Hills. The sandstone slopes of these hills are sparsely scattered with the candelabra Euphorbia (*Euphorbia erythraeae* N. E. Br.), the dragon's blood tree (*Dracaena ombet* Kotschy & Peyr.) and 'samr', with a ground cover

of *Aizoon canariense* Linn., *Blepharis linariaefolia* Pers., with its attractive blue flowers, *Zygophyllum simplex* Linn., prickly *Barleria* spp., and other drought-resisting herbs. Where the underlying rock is replaced by granite and the hills receive the benefit of the winter rains a more luxuriant evergreen vegetation persists. This is particularly evident at Erkowit, where occurs a peculiar pocket of vegetation which will be described in a separate section.

In the Red Sea Hills area the dry watercourses which spread out into large plains are almost invariably lined with dom palms. 'Samr' is the

FIG. 3. *Dracaena ombet*, showing one plume of blossom, and *Euphorbia erythraeae* are index trees of one of the floral zones at Erkowit (*photo H. W. B. Barlow*).

predominant Acacia. A feature of many of the hills in the southern and central parts of this area is *Delonix elata* Linn. (= *Poinciana elata* Linn.) with its large, attractive, white-orange flowers.

Near the sea the flora often consists of almost pure 'adlīb' (*Suaeda monoica* Forsk.) mixed with *Suaeda vermiculata* Forsk., *Suaeda volkensii* C. B. Cl., *Atriplex farinosa* Forsk., *Trianthema crystallina* Vahl., *Fagonia cretica* Linn., and *Lotus glinoides* Del., while above the water's edge is the common sand-binding grass *Aeluropus lagopoides* Druce. On muddy shores south of Suakin, *Avicennia marina* Stapf, and mangroves (*Rhizophora* sp. and *Bruguiera* sp.) occur.

Along the Atbara river are found groves of dom palms, scattered trees of 'sallam', 'samr', and 'heglīg', and the shrub 'tundub' *Capparis decidua* Pax. On the banks of both this river and the Nile can be seen clumps of the riverside shrub *Ficus capreaefolia* Del.

In the northern part of the region west of the Nile, where stretches of light clay and areas of stone and gravel with rocky outcrops may be seen,

the ground vegetation consists essentially of tufts of annual grasses such as *Aristida funiculata* Trin. & Rupr., *A. adscensionis* L., *A. steudeliana* Trin. & Rupr., and 'haskanīt'. *Blepharis* spp. with their striking blue flowers may occur in thick patches in depressions. The sides of small seasonal watercourses are often lined with tussocks of 'maharīb' (*Cymbopogon proximus* Stapf), *Tephrosia nubica* Baker with its densely white silky pods, *Indigofera suaveolens* Jaub. & Spach and the grasses *Lasiurus hirsutus* Boiss. and *Sporobolus helveolus* Durand & Schintz. (*S. glaucifolius* Hochst.). Larger sandy beds may contain the white or tawny herb or undershrub

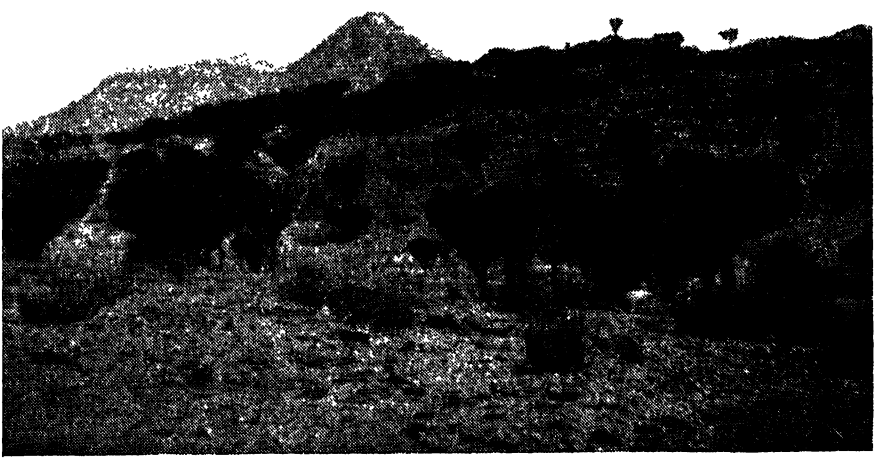


FIG. 4. Erkowit Plateau: Arid Zone: showing dominant *Euphorbia erythraeae* N. E. Br., with *E. thi* Schweinfth., *Acacia etbaica* Schwfth., and *Carulluma penicillata* N. E. Br.

Chrozophora oblongifolia A. Juss. and abundant 'tumām' grass. On hard open ground there may occur scattered trees and shrubs, mainly 'kitr', 'kurmut', 'tundub', 'seyal' (*Acacia raddiana* Savi.), the small spiny tree *Commiphora africanum* Engl., *Cadaba glandulosa* Forsk., with its rather sticky leaves, and *Maerua crassifolia* Forsk.

This region to the west contains vast stretches of 'qōz' country, a country of rolling sand varying from gentle undulations to dunes 100 ft. high. The soil is often fairly hard on the surface where undisturbed by cultivation and may be fairly thickly covered with undershrubs or grasses; no trees occur, but 'marakh' may grow as scattered bushes up to 12 ft. high or as thickets. There is often a ground cover of the sedge *Pycreus mundtii* Nees and *Panicum* sp. with undershrubs of *Bouchea marrubiifolia* Shauer, *Melhania denhamii* R. Br., *Crotalaria thebaica* DC., and common annuals such as 'haskanīt', *Tragus racemosus* All., *Eragrostis* spp., and *Blepharis* spp. On the tops of high dunes where sand is looser *Chrozophora oblongifolia* A. Juss. may be seen.

The boabab tree, *Adansonia digitata* Linn. ('tebeldi') so abundant in the next region occurs occasionally in the western portion of this region (*v.* Fig. 210 on p. 518).

3. *Acacia Short-grass Scrub Region*

This region forms a narrow belt bounded by Dueim and Fasher in the north and Gedaref, Singa, and Um Ruaba in the south. It skirts the northern boundary of the Jebel Marra massif, where the belt narrows considerably. The annual rainfall of this area is from 12 to 20 in. with a drought period of 4–6 months. This region differs from the preceding one in that the rainfall is sufficient in quantity and lasts for a sufficient time to bring to maturity many grasses and herbs, and to maintain a rather open woodland type of country. The soil, too, is in general, more water-retaining. Its principal botanical interest lies in the fact that the Combretaceous belt which stretches across Africa has its northern limit at the southern boundary of this region, in particular where it impinges on the northern boundary of the Nuba Mountains district. The dominant trees are still *Acacia* spp., but the variety of trees is greater than in the preceding region and there are many indications that the climatic conditions are more suitable for broader-leaved trees. The eastern boundary of this region is formed by the junction of the Sudan with Eritrea, and the Karora Hills lying almost on this boundary have many floristic affinities with the hills of Eritrea. 'Tebeldi' (boabab) is abundant in the western portion of this region. Near the Gash river are large forests of 'tarfa' (*Tamarix articulata* Vahl.) with its grey-green minute leaves clinging closely to the stems and pale pink flowers, 'sidr' and *Acacia* spp., while in the flood plain of this river are abundant tall trees of 'usher' (fig. 5) with 'dahassir' and 'kurmut' (*Cadaba rotundifolia* Forsk.) and the leafless 'tundub' as dominant shrubs. The herbaceous flora over the flooded cotton-growing area contains principally 'sēd' grass (*Cyperus rotundus* Linn.), 'mordēib' (*Paspalidium desertorum* Stapf), 'adār' (*Sorghum* spp.), *Shouwia arabica* DC. with its purple flowers, and various Malvaceous weeds. Away from the river, where there are trees or shrubs at all, these are predominantly 'tundub', 'mokhēt', and 'kurmut', while around Kassala town are 'la'ōt', 'samr', 'tarfa', and *Cordia gharaf* Ehrenb. *ex* Aschers. (= *C. rothii* Roem. & Schult.).

North of Gedaref the country, which includes the almost treeless Butana desert, is essentially an open grass plain of often heavy soil with thorn scrub and often abundant 'kitr'. Taller grass and denser shrubs and trees, e.g. 'tarfa' and 'sidr', occur near the Atbara river. This river in this area traverses a practically level grass plain covered with thorny bushes. Along the banks themselves the mixture of thorn bushes, grasses, and creepers is often very dense. Towards its upper reaches, 'dōm'-palm forests may occur.

The Rahad and Dinder rivers both run through open country save for a fringe of 'sunt', 'talh', and 'seyāl'. Between the two rivers there are large open areas with scattered thorny scrub. The latter river being larger than the former is more densely wooded, though with the same species, and

some 20 miles up its course occur some of the most northerly examples of the 'dolēb' palm (*Borassus aethiopium* Mart.).

Along the banks of the Blue Nile will be found 'tarfa', the two Sudan representatives of the Willows, both known as 'safsaf', viz. *Salix muriellii* Skan. with its silky leaves, and *Salix subserrata* Willd. with glabrous leaves, the latter being actually more common on the Nile north of this area, and the fragrant pale cream-flowered *Kanahia laniflora* R. Br.

The country between the Blue and White Niles, the northern part of which is known as the Gezira, where cotton is cultivated under irrigation from the Sennar Reservoir, consists largely of a dark heavy cracking clay. In general it bears coarse grasses and herbs and more or less scattered patches of 'kitr', 'la'ōt', 'sidr' ('nabag'), 'tundub', and such shrubs as 'mokhēt', *Grewia* spp., and *Cadaba farinosa* Forsk. Slightly to the west of Sennar stand two minor groups of rocky granitic hills, Jebel Sagada and Jebel Moya, which bear a flora of a type common on these granitic hills, viz. the graceful 'sahab' (*Anogeissus schimperi* Hochst.) with its fruit gathered together like small brown fir-cones, *Lannea* spp. (= *Odina* spp.), and the large *Sterculia tomentosa* G. & P. with its smooth dappled bark and large fruit with irritating hairs, *Commiphora africana* Engl., *Ficus* spp., *Lonchocarpus laxiflorus* G. & P. with its bunches of attractive light purple flowers, *Grewia* spp., and 'mokhēt' with a ground cover of short grasses and the little blue-flowered *Evolvulus alsinoides* Linn., the red to purple-flowered *Monsonia senegalensis* Guill. and Perr., *Aizoon* spp. *Blepharis* spp., *Ammanis senegalensis* Lam., and *Polycarpaea* spp.

Westwards of the White Nile the land gradually merges into 'qōz' country, where occur scattered bushes of 'marakh', with occasional 'harāz' and a number of grasses mixed with drought-enduring plants such as *Polycarpaea* spp., *Monsonia senegalensis* Guill. and Perr., *Heliotropium* spp., *Evolvulus alsinoides* Linn., and several herbaceous *Euphorbias*. Farther west still, 'harāz' and 'hashāb' (*Acacia senegal* Willd.) become more numerous until the country is covered with a fairly continuous open forest of the latter which yields here the gum Arabic of commerce.

Near seasonal watercourses at the southern limit of this region occur *Terminalia* spp., *Bauhinia* spp., and 'babanūs' (*Dalbergia melanoxylon* G. & P.), outliers of the next vegetation region.

In the south-east corner of the Sudan occurs another Acacia short-grass area (see vegetation map on p. 34 and fig. 6). This is an arid region forming the northern extremity of the arid portion of northern Kenya. To the east, where it is bounded by the rocky hills of Abyssinia, occur rocky plateaux interrupted by grassy plains, often wooded. To the west and south are seen open grass plains often of dark heavy clay soil with often abundant 'heglīg'. Areas of thick thorn trees and bush occur, and 'kitr' may be dominant. Along the rivers and the seasonal watercourses may occur vast swamps, permanent or formed only during the rains. Along the banks, broad-leaved trees may be seen, e.g. 'qammēz', 'aradēb' (*Tamarindus indica* Linn.), a large shapely tree with dark-coloured fissured bark and fruit with a red acid pulp, and the sausage tree (*Kigelia aethiopica* Decne). 'Kūk' (*Acacia sieberiana* DC.) is also prominent near the rivers as well as thick scrub.

4. *Acacia Tall Grass Forest Region*

This region is somewhat triangular in shape with a broad extension to the west bounded on the south by the Bahr el Arab. The limits of this region are best noted by a glance at the vegetation map. The region has an annual rainfall of about 20–40 in. and includes three botanically important groups of highland, the Jebel Marra group, the Nuba Mountains, and the Ingessana Hills. It includes also the vast seasonally inundated swamps along the White Nile river known as 'toich', as well as the permanent swamps that line the free water of the river and form the so-called 'sudd'. These swamps will be considered under their separate headings.

This region contains diverse types of soil with their concomitant types of vegetation, from dark heavy clay to light sandy loams, granitic hills as in the Nuba Mountains and Ingessana Hills, and alkaline clay near the White Nile. The region is, however, just outside the main red ironstone country which occurs in the next region.

The floristic composition of this region shows a great change from that of the preceding one. *Acacia* spp. are still prominent, but the introduction of Combretaceous and other broader-leaved trees alters the whole outlook of the landscape. The region in places presents a picture of almost thick vegetation with heavy ground cover quite distinct from preceding regions. Changes occur in the species of Acacia; sunt rarely occurs south of Jebelein and is replaced by 'kūk', which becomes one of the most important Acacias of the Southern Sudan.

In this region 'talh' attains its best development on heavy clay, while on lighter limy soils occurs a broader-leaved flora including *Terminalia* spp., *Combretum* spp., *Guiera senegalensis* J. F. Gmel. with its fruit covered with pink silky hairs, 'aradēb', and the sausage tree.

In the neighbourhood and south of Gedaref occurs a cracking clay soil with thickly wooded country of abundant *Acacia fistula* Schwfth. with its white bark and swollen thorns, 'talh' and 'hashāb', the last being, in places, thick enough to form gum forests. 'Heglīg' is also abundant in places, and non-thorny trees such as *Combretum* spp. occur on lighter soils. To the north is found open grassland with abundant 'talh' and some 'hashāb' and 'kitr'. The east of this district is bounded by the Abyssinian hills and the broader-leaved flora of rocky lighter soils intrudes.

East of the Dinder the country is undulating with occasional hills and rock outcrops. On the heavier soils occur abundant 'hashāb', 'heglīg', 'talh', and *Acacia fistula* Schwfth., while the lighter soils contain *Combretum* spp., *Lonchocarpus laxiflorus* G. & P., *Sterculia tomentosa* G. & P., 'kadada' (*Dichrostachys glomerata* Choiv.) with its flowers in dense pink and yellow heads and much twisted pods, 'tebeldi' (boabab), 'la'ōt', 'sahab', with occasional 'heglīg', 'homēd' (*Sclerocarya birrea* Hochst.) with purple flowers and edible yellow fruit, *Randia nilotica* Stapf, and *Grewia villosa* Willd. The dōm palm is widely distributed over the district. The tall grass ground cover consists essentially of *Hyparrhenia* spp., *Cymbopogon giganteus* (Hochst.) Choiv., *Brachiaria* spp., 'nāl', 'adār', while among the smaller grasses and herbs are 'haskanīt', *Setaria* spp., *Cassia occidentalis* Linn., *Alysicarpus monilifer* DC., and *Monechma bracteatum* Hochst. On

very light shallow soils may be found *Aristida funiculata* Trin. & Rupr. and *Blepharis linariaefolia* Pers. The convolvulaceous creeper, *Ipomoea hispida* Roem & Schult (= *I. eriocarpa* R. Br.) is abundant in most places. Where the soil is heavy and flooded during the rains may occur abundant *Asteracantha longifolia* (L.) Nees. (= *Hygrophila spinosa* T. Anders in B. & M.) with its spines and mauve-coloured flowers. On rocky hills and outcrops of sufficient size are found *Commiphora* spp., 'taraktarak' (*Boswellia papyrifera* Hochst.), with its loose papery bark and pink flowers, and *Ficus* spp.

FIG. 5. Pure stand of 'ūsher' (*Calotropis procera* Ait.) lining water channel in the Gash cotton area.

One of the commonest weeds of cultivation is 'danab el kalb' (*Celosia argentea* Linn.).

The land between the Dinder and Blue Nile rivers consists of a more or less flat plain on either side of which the land slopes down to the river. The soil is mostly a dark heavy brown cracking clay with lighter soils near the rivers. On the central plain the principal constituents of the thorn vegetation are 'heglīg', 'talh', and 'kitr' associated with 'la'ōt', 'hashāb', 'kadada', 'sidr' ('nabag'), 'tūndub', 'mokhēt', and *Acacia fistula* Schweinf., with an undergrowth of such grasses as 'nāl', 'adār', *Brachiaria* spp., *Rottboellia exaltata* Linn. f., and *Hyparrhenia pseudo-cymbaria* Stapf. On the grassland areas are found scattered trees, including 'heglīg' and bushes such as 'kurmut'. On the river flats sunt is dominant with an undergrowth of various grasses. On the land sloping to the rivers the principal trees and shrubs are 'heglīg', 'talh', and 'kitr', though in places 'tundub' may be abundant. Other trees include those mentioned above in the plain, and along the Dinder 'dolēb' palms may be found, as well as an occasional 'tebeldi' (Boabab). Near villages occur 'la'ōt' and 'ūsher'. Beside sandy

watercourses, in addition to those trees and shrubs seen on the sloping ground may also be seen *Combretum* spp.

The Blue Nile is a relatively rapidly flowing, meandering river, subject during the rains to a large rise in level when the water-colour changes from the limpid blue of the dry season to a chocolate brown due to the silt and scourings that it brings down from the Abyssinian hills. In consequence principally of its rapid flow, there is little plant growth in the river itself. In its winding course the river forms, however, shallow mud-flats called 'maya' which are flooded when the river is in flood and become dry again when the river recedes. On these mud-flats grow forests of principally sunt with a ground cover on the drier parts and surrounding land of *Cassia occidentalis* Linn., *Desmodium sennaarense* Schwfth., *Wissadula amplissima* var. *rostrata* R. E. Fries, *Peristrophe bicalyculata* Nees, *Setaria* spp., *Achyranthes aspera* Linn., and *Xanthium strumarium* Linn. in low places. The water on these 'maya' is shallow and relatively stagnant, and it is there that water plants abound. These plants will be described under the section 'The Water Plants of the Blue Nile River, the Sennar Reservoir, and the Gezira Canals'. Along the banks of the Blue Nile from Singa southwards, prominent plants are 'sidr', 'tarfa', *Ficus capreaefolia* Del., and *Cordia abyssinica* R. Br. Inland from the banks are seen clumps of 'dolēb' palms and occasionally the shapely *Celtis integrifolia* Lam. with smooth pale grey bark and leaves with prominent 3 to 5 nerves and unequal-sided base, while as we go upstream 'tebeldi' becomes more frequent, and 'dōm' palms become more plentiful than 'dolēb' palms. South of Singa, just west of the Blue Nile, is a rolling grass plain with principally 'heglīg', 'aradēb', 'talh', 'sidr', and occasional 'tebeldi' trees. 'La'ōt' and 'kitr' are common, and when the soil becomes light and sandy, 'talh' almost disappears and *Combretum* spp., principally *C. hartmannianum* Schwfth., with its long pointed leaves are seen. Sunt is present in seasonally watered watercourses. Abundant *Achyranthes aspera* Linn., *Leonites* spp., *Solanum incanum* Linn., and *Bidens pilosa* Linn. are seen in the ground cover.

As we approach the Ingessana Hills, *Sterculia tomentosa* G. & P., *Bauhinia* spp., and 'dōm' palms become common, and 'taraktarak' and *Ficus* spp. occur on the rock outcrops. The bamboo (*Oxytenanthera abyssinica* Munro) becomes common on the banks of seasonal watercourses.

At and around Kurmuk, which lies almost on the Abyssinian border and under the influence of the Abyssinian hills, red sandy loams occur, with thick bush country and sometimes long grass forest. The 'tebeldi' (boabab) is common here, and not far away occurs Jebel Tornasi, 'the evergreen hill', which has perennial springs almost to the top so that the hill is permanently green with vegetation.

To the west of the Ingessana Hills and of Kurmuk is an open grass plain of essentially heavy soil, often swampy in the rains, with patches of thick 'talh', and 'heglīg', occasional *Combretum* spp., and a few rock outcrops. 'Dōm' palms in clusters often occur. This type of country persists to the White Nile and with variations throughout the whole of the southern part of this region, the 'dōm' palm being often replaced by the

dolēb. It is essentially a cattle-owning country with agriculture as a secondary occupation. This southern portion of the 'acacia tall grass forest region' is interspersed with numerous rivers and watercourses, mostly tributaries of the White Nile, and these watercourses in the flat grass plain produce during the rains vast seasonal swamps with often thorny vegetation on the higher land.

East of Malakal is an open grass plain of dark cracking clay interrupted by swamps, with 'talh' and occasionally abundant *Acacia fistula* Schweinf. Along the Sobat river occur groves of 'dolēb' palms, 'harāz', and *Celtis integrifolia* Lam., and occasionally dense forests of 'talh' often mixed with

FIG. 6. Scenery near Kapoeta with giraffes and *Acacia fistula* (*photo H. Greene*).

'hashāb'. The district around Nasir on the Sobat river is again an open grass plain of heavy soil often flooded during the rains with the formation of large swamps, and on the higher ground 'heglīg' forests may occur. To the east of Nasir the country is influenced by the Abyssinian hills; the soil becomes lighter and *Combretum* spp. and other broader-leaved trees occur. West of Nasir the open plain of heavy soil continues, covered with scattered 'sidr' ('nabag') and scrub. Around Fangal (Lake No) and Adok large swamps line the rivers and watercourses. On the higher land are found 'talh' forests, thick bush, scattered 'heglīg', 'dolēb' palms, and occasional 'qammēz' and 'aradēb'. To the west of Daka Fort occur vast swamps, while forests are seen along the Yabūs river with scattered sausage trees, *Terminalia* spp., and *Combretum* spp., and granite outcrops as we approach the Abyssinian border. East of Bor the open grass plain of heavy soil still persists, with large swamps, scattered trees, thorn bush, and occasional 'aradēb' and other trees on the higher ground. West of the White Nile and to the north of the Nuba Mountains there is an open grass plain of reddish sand varying in colour as the proportion of clay increases, a continuation of the scenery of El Obeid in the previous region. As

we approach the Nuba Mountains the vegetation increases in density and trees become larger. *Combretum hartmannianum* Schwfth., *Guiera senegalensis* J. F. Gmel., and 'arrāda' (*Albizzia sericocephala* Benth.) are common, and the shrubby *Euphorbia venenifica* Trem. appears together with, on rocky outcrops, the crimson-flowered poison tree (*Adenium honghel* A. DC.). To the east, before entering the Nuba Mountains proper, we have on the north the large seasonal watercourse the Khor Abu Habl, which consists of a wide stretch of dark heavy clay with abundant 'talh', sunt, and tall and medium grasses. South of Khor Abu Habl is an open grass sandy plain with 'kitr', 'sahab', *Terminalia* spp., and *Dobera roxburghii* Planch,

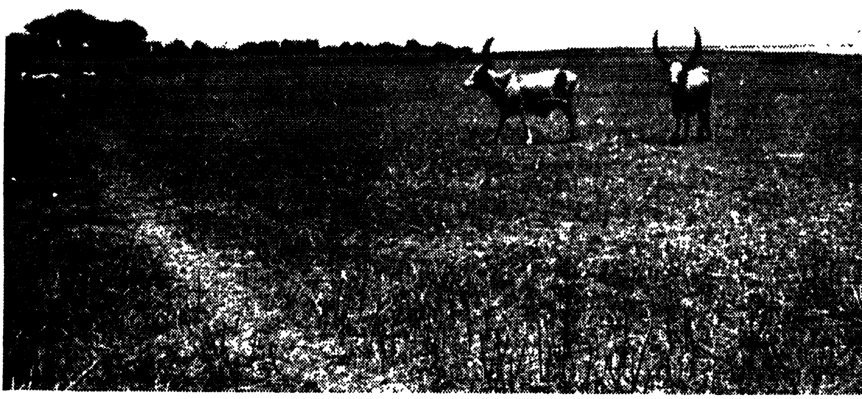


FIG. 7. Typical grazed 'toich' land near Lake Yirol: note long-horned Dinka cattle (*photo H. Greene*).

and as we go farther south, 'la'ōt', the candelabra Euphorbia, *E. calycina* N. E. Br., 'hashāb', 'mokhēt', and 'kadada' become prominent.

The Nuba Mountains consist of a series of ranges of large granitic outcrops which are covered with a comparatively shallow soil. The area is of interest botanically owing to the number of species flourishing there which really belong to more southern regions. In the valleys and the plains separating the hills there is often dark heavy soil and the vegetation is often predominantly thorny. On Jebel Daier, the most northerly massif of the Nuba Mountains, may be found the most northern specimens of the bamboo, *Oxytenanthera abyssinica* Munro, the small tree *Steganotaenia araliacea* Hochst. (= *Peucedanum fraxinifolium* Hiern), *Croton gratissimus* Burch., *Vitex cuneata* Schum. & Thonn. (= *Vitex cienkowskii* Kotschy & Peyr.), and *Allophyllus rubifolium* Hochst. (= *Schmidelia rubifolia* Hochst.). Also frequent on the rocky shallow soils are 'taraktarak', *Commiphora africanum* Endl. and *C. pedunculata* Engl., and the pink- or red-flowered poison tree, *Adenium honghel* A. DC. On light soils flourish the Combretaceous type of vegetation (principally 'sahab', *Combretum* spp., and *Terminalia* spp.) as well as those trees, shrubs, and herbs re-

corded above as occurring generally on granitic outcrops (see 'Acacia short grass scrub region'). To this list must be added *Dombeya quinqueseta* (Del.) Exell. (= *D. multi flora* Planch. var. *vestita* Schum.), *Pseudocedrela kotschyi* Harms., and *Sclerocarya birrea* Hochst. *Ficus* spp. are frequent, two of the commonest being the large tree *Ficus platyphylla* Del., with its broad leaves up to 10 in. long growing on the flatter ground and the smaller *F. populifolia* Vahl. on rocks. Bāobab are frequently met with, and near the sandy edges of watercourses will be found the ebony, *Diospyros mespiliformis* Hochst. and *Celtis integrifolia* Lam. In the valleys and on

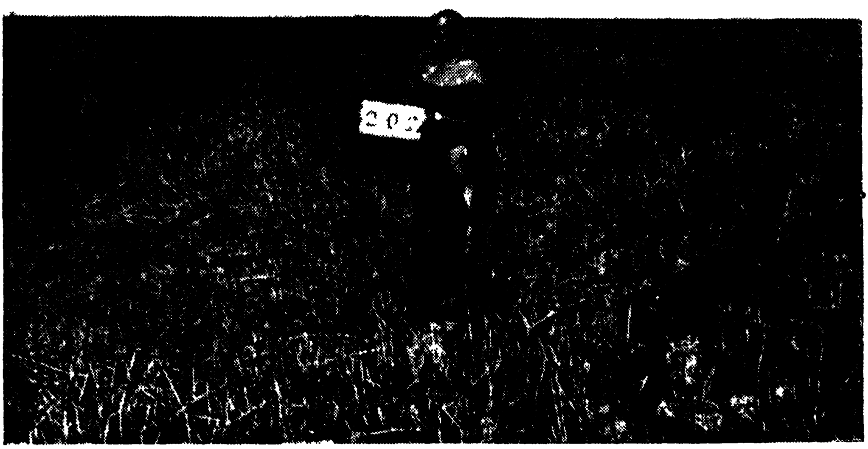


FIG. 8. 'Toich' land towards end of dry season: grass generally burnt over (*photo H. Greene*).

the heavier soils the thorny flora consists of 'talh', 'harāz', 'kakamūt' (*Acacia campylacantha* Hochst.), and 'kadada' and in places 'kūk', 'sidr', and 'heglīg' may become dominant. 'Arrāda' (*Albizzia sericocephala* Benth.) is common on the flatter land where the candelabra Euphorbia, *Euphorbia calycina* N. E. Br., can be seen. Both tall and short grasses are present, the most important of the former being *Hyparrhenia* spp., *Brachiaria* spp., 'adār', and 'nāl', and of the latter *Ctenium elegans* Kunth, *Pennisetum mollissimum* Hochst., and *Setaria* spp. Along the sandy banks of seasonal watercourses may be seen *Vitex cuneata* Schum. & Thonn, *Vernonia amygdalina* Del. with its bunches of fragrant white flowers, *Carissa edulis* Vahl., *Woodfordia floribunda* Salisb., and the sausage tree, 'khashkhash' (*Stereospermum kunthianum* Cham.) with its beautiful pink-violet flowers, while bamboo may be abundant locally.

West of the Nuba Mountains and through Darfur we have gently rolling country with often 'qōz' sand towards the northern portion and heavier soils to the south. Granitic outcrops are seen and alluvial soil may

occur along the seasonal watercourses. Among the trees and shrubs are 'heglīg', 'la'ōt', 'kadada', 'homēd', 'mokhēt', dōm palms, 'arrāda', 'aradēb', 'sahab', 'hashāb', and *Bauhinia* spp., with *Combretum* spp., *Diospyros mespiliformis* Hochst., *Ximenia americana* Linn., *Prosopis africana* (G. & P.) Taub. (= *P. oblonga* Benth.), *Gardenia lutea* Fres, *Vitex cuneata* Schum. & Thonn. (= *V. cienkowski* Kotschy & Peyr.), and the small-leaved Sudan mahogany, *Khaya senegalensis* A. Juss., appearing as we proceed south. The 'tebeldi' (Fig. 210) is frequent throughout this part of the region, but becomes scarcer as we near the Bahr el Arab, which appears to be its southern boundary.[1] 'Talh' may be dominant on the clay plains.

Jebel Marra is of interest botanically in that its upper slopes are sparsely covered with an olive tree (*Olea chrysophylla* Lam.) and *Acacia albida* Del. The former constitutes the sole representative of arboreal life in the zone above 8,500 ft., while the latter just before reaching its limiting altitude exists only as dwarf trees or bushes.

5. *Broad-Leafed Woodland and Forest Region*

This region, which includes land both east and west of the Nile, is bounded on the north by the Bahr el Arab and lies for the most part in the south-western portion of the Sudan where it abuts on the boundaries of Uganda, the Belgian Congo, and French Equatorial Africa. It is the region of the red ironstone country and has an annual rainfall of 40–60 in. In places the vegetation is extremely luxuriant and in it, in miniature, occur the broad-leaved closed forests that are so extensive in Uganda and the Belgian Congo.

The forests of this region as well as the grasslands will be dealt with under their separate headings. The north-eastern portion of the region contains large stretches of seasonally inundated land known locally as 'toich'; this will be described under the section dealing with swamps. In this present description only what may be called grass woodland will be described.

With the multiplicity of species and diverse types of vegetation contained in this region it is only possible in this brief account to deal with the vegetation in the very broadest outline.

To the south-west of the region comprising roughly the districts of Yei, Meridi, and Yambio we have an area of high grass woodland where the bulk of the most luxuriant vegetation occurs. It is the area where the elephant grass (*Pennisetum purpureum* Schum.), the tallest grass in Africa, and the tall *Urelytrum giganteum* Pilger abound. This area contains closed depression forests (see later) and extensive gallery forests (see later) lining the banks of the rivers. The aggregate of gallery forests must be considerable, while the whole country between these strips is covered with tall grass and assorted trees, interrupted only by scattered mountain peaks, low domes, and other rock outcrops. The density of tree growth varies from a patchily closed canopy or at least tree-tops touching to open orchard bush or even fewer trees, while the ground cover is a multiplicity of shrubs and herbs and grasses from 6 to 15 ft. high. Characteristic trees and

[1] At suitable elevations baobab is, however, common on the coastal plains of Kenya and Tanganyika.—*Editor*.

bushes are: the shea butter tree (*Butyrospermum niloticum* Kotschy)—known in Arabic as 'lulu', with black rugged bark, large leathery leaves crowded at the ends of branches, *Lophira alata* Banks with strap-shaped smooth glossy leaves, large fragrant white flowers and fruit like a shuttle-cock, *Combretum binderanum* Kotschy (= *C. populifolium* Engl. & Diels), *Terminalia mollis* Laws. (= *T. torulosa* F. Hoffm.), *Entada sudanica* Schweinf., the shapely *Afzelia africana* Smith, with its large thick black seeds, orange at one end, the tall *Daniellia oliveri* Hutch. & J. M. Dalz (called *D. thurifera* Bennett in Broun & Massey) with its cylindrical pale

FIG. 9. Grassland induced by shallow soil: near Maridi, with somewhat thin broad-leaved forest in the background.

grey bole and fragrant flowers, *Pterocarpus abyssinicus* Hochst., *Acacia sieberiana* DC., and *Acacia campylacantha* Hochst. Abundant grasses are *Imperata cylindrica* Beauv., characterized by its silvery fluffy heads, elephant grass (*Pennisetum purpureum* Schum.), *Pennisetum polystachyon* Schult., *Rottboellia exaltata* Linn. f., with its narrow long cylindrical heads, and guinea grass (*Panicum maximum* Jacq.). The graceful tree *Anogeissus schimperi* Hochst., already mentioned as occurring as far north as Jebel Moya, also occurs in this area but shows a curiously restricted distribution, being abundant in the Yambio and Meridi district, absent from almost the whole of the Yei district, and uncommon on the Juba–Torit and Juba–Nimule roads. This curious distribution (it is absent from Uganda) is thought to be explained by elevation. It is, however, well known that *Anogeissus schimperi* Hochst. prefers sandy, gravelly well-drained soil types and is practically absent from heavy clays.

The area of high grass woodland grades almost imperceptibly as we proceed north into an area of less tall grass but still maintaining a mixed collection of trees. The trees like the previous area vary in density from

an open park-like growth to a relatively dense stand. The grasses, which vary from 4 to 6 ft. in height, are not dense but form rather an open cover. Characteristic trees are *Terminalia mollis* Laws. (= *T. torulosa* F. Hoffm.), the small-leaved Sudan mahogany (*Khaya senegalensis* A. Juss.), *Parkia oliveri* Macbr. with dense pendulous heads of scarlet flowers and long flat pods, the long-pointed leaved *Combretum hartmannianum* Schwfth., *Burkea africana* Hook. f., *Entada sudanica* Schwfth., *Prosopis africana* (G. & P.) Taub. (= *P. oblonga* Benth.), *Dalbergia melanoxylon* G. & P., of irregular growth and fissured white trunk, and the ebony

FIG. 10. Typical close woodland around Mt. Bengenze.

(*Diospyros mespiliformis* Hochst.), while locally occur dense stands of *Isoberlinia doka* Craib & Stapf (called *Berlinia acuminata* Solander in Broun & Massey) with its very long, broad, green-brown velvety pods which curl up spirally after shedding their seeds. This tree, similarly to *Lophira alata* Banks in the previous area, is indicative of the poorer shallower soils. Many prominent termite hills are scattered throughout the area, and the larger and older hills are covered with vegetation. Among the prominent grasses are *Hyparrhenia rufa* (Nees) Stapf, *Brachiaria brizantha* Stapf, *Setaria sphacelata* Stapf & Hubbard, *Trichopteryx gigantea* Stapf, and *Rhynchelytrum repens* C. E. Hubbard.

As has been mentioned previously, this general grass woodland aspect of the west of the Nile is interrupted by rocky outcrops and small mountains. Two of the most prominent of the latter are Mt. Bengenze and Mt. Loka. The former (Fig. 10) occurs on the Sudan–Belgian Congo border somewhat to the south-west of Meridi and is about 3,500 ft. high. It has comparatively little vegetation on it except in gullies, large parts of the mountain being naked rock. Many beds of *Aloe* spp., with reddish leaves

and long stalks of magnificent flame-red flowers, occur in crevices, as does the orchid *Eulophia baginsensis* Reichb. with its coarse tooth-edged leaves and long stalks of reddish-brown flowers. Among other plants of the higher rock slopes are a few grasses, a common sedge (*Eriospora schweinfurthiana* C. B. Cl.), an *Aeolanthus* sp. with small blue flowers and a strong camphor-like smell, and the almost leafless sprawling *Sarcostemma viminale* R. Br. with its cylindrical stem, clusters of yellow flowers, and milky juice.

Mt. Loka is a much bigger peak than Mt. Bengenze, being 5,500 ft. high, and is situated to the north-east of Yei. With the exception of Jebel Marra it is the highest peak in the Sudan west of the Nile. This mountain is covered on its slopes with bamboo of varying density, and with *Terminalia* and *Combretum* spp., while *Pterocarpus abyssinicus* Hochst., with its fragrant yellow flowers and winged disk-like fruit, is often frequent on the way up. On a huge shelf at the base on the final rock-dome occurs a grove of luxuriant rain forest with abundant large, tall *Cola cordifolia* (Cav.) R. Br., with its very large leaves, while *Dracaena steudneri* Schweinf. *ex* Engl. is the common understory tree. On bare black rock slopes occur patches of the camphor-smelling blue-flowered *Aeolanthus* sp., and the red-flowered *Aloe* sp. of Mt. Bengenze. At the 4,900-ft. level *Protea madiensis* Oliv. appears mixed with *Hymenocardia acida* Tul., while bamboo ceases at about 5,150 ft. *Protea madiensis* Oliv. is the principal tree, sometimes stunted, almost to the summit together with bushes of *Psorospermum campestre* Engl., with its frilled white flowers, and the shrubby *Senecio multicorymbosus* Klatt.

In the northern part of this region we have a more thorny woodland suggesting that conditions are becoming drier. *Acacia* spp., *Ziziphus* spp., and *Combretum* spp., *Terminalia* spp., are especially abundant and form important constituents of the woody vegetation. The trees are often much wider apart than in the two southern areas. 'Talh' and the flat-topped 'samr' occur locally in quantity, while the 'tebeldi' (boabab) may very rarely be found at the extreme north of the region. The grass cover is similar to the previous area.

In the portion of this region east of the Nile we have essentially medium grass woodland with swamps in the northern extremity. In the central and southern portion occur abundant rock outcrops culminating in the Acholi, Immatong, and Dongotona Mountains and Didinga Hills which abut on to the Sudan–Uganda border. Immediately east of the river is an open plain which at first contains rather thorny vegetation, but as we proceed eastwards the bush and tree vegetation rapidly changes. It becomes more close, varied, and broad-leaved, while the plain gradually rises and is interrupted by rock outcrops which are sometimes large enough to form hills. *Sarcocephalus esculentus* Afz. (= *S. russeggeri* Kotschy.), *Crateva adansonii* DC., *Combretum* spp., *Terminalia* spp., *Prosopis africana* (G. & P.) Taub., *Khaya senegalensis* A. Juss., and the shea butter tree are common among the trees with a very occasional *Anogeissus schimperi* Hochst. The principal grasses are *Hyparrhenia* spp., while elephant grass may fringe the watercourses around the bases and along the ravines of the larger hills and mountains.

6. *Forests*

(*a*) *Gallery Forests*. Gallery forests occur as fringes along the margins of the larger streams and are enabled to exist under a lesser rainfall by the more abundant ground-water. They are restricted in quantity on the west of the Nile to the high grass woodland country of the southern portion of the Broad-leaved Woodland and Forest region and reach their richest development in the south-west of Yambio district, though they are well developed also on the Aloma plateau south of Yei. They also occur in quantity along the streams towards the base and up the ravines of the mountains and hills of the portion of this region east of the Nile.

Gallery forests on smaller streams consist only of a single ranked fringe dominated by *Syzygium owariense* Beauv. (called *S. guineense* (Willd.) DC. in Broun & Massey) with its very dark scaling bark and tough, smooth, waxy, grey-green leaves, and the ebony (*Diospyros mespiliformis* Hochst.). As we proceed downstream the heavier gallery forest trees, notably the larger leaved mahogany, *Khaya grandifoliola* C. DC. (= *K. dawei* Stapf) come in, ranks increase, a closed canopy is formed, and rain forest conditions prevail, with an evergreen shrubby undergrowth, and in the bottoms a riot of broad-leaved Marantaceous and Zingiberaceous plants, climbing palms, and *Pandanus* spp., with its long sword-like sharply toothed leaves. Still farther downstream, when the river passes out of the high grass woodland area, the belt narrows again, becomes once more a fringe dominated by *Syzygium owariense* Beauv., with the large-leaved mahogany and other large trees only at intervals, finally disappearing as *Irvingia smithii* Hook. f. comes in and becomes dominant in a single ranked fringe. A list of the large trees of a typical gallery forest would contain the larger-leaved mahogany (*Khaya grandifoliola* C. DC.), *Cola cordifolia* (Cav.) R. Br., with its huge leaves, *Chlorophora excelsa* (Welw.) Benth. & Hook. f., one of the tallest forest trees with grey-brown bark and a milky juice, the large, often huge, *Erythrophleum guineense* G. Don. with black woody pods, the kapok or silk cotton tree (*Ceiba pentandra* Gaertn.), *Mitragyna stipulosa* (DC.) O. Ktze. (= *M. macrophylla Hiern.*) with its knee-roots protruding above the ground, and large, dark green, shiny leathery leaves, and *Canarium schweinfurthii* Engl., exuding a resin which is used for torches. The trees often have the large epiphytic fern *Platycerium angolense* Welw. growing on them.

(*b*) *Bowl or Depression Forests*. The depression forests are the nearest approach in the Sudan to the true climate rain forest such as exists on the Amazon or the Congo. These forests, as the name implies, occur in depressions where there may or may not be a stream, but where they receive the run-off in the wet season from the surrounding slopes. These forests in the Sudan are small in extent, Azza Forest, situated in Meridi district, being only about 1,760 acres in extent. The most abundant top story tree of this forest is *Holoptelea grandis* Mildbr., with patchy yellow to orange, scaly bark and small winged fruits. This tree is a frequent host of the epiphytic fern *Platycerium angolense* Welw. Other abundant tall trees are *Mildbraediodendron excelsum* Harms., with yellow fruit about the size and shape of a tennis ball, *Schrebera macrantha* Gilg. & Schellenb., with smooth, pale yellow-brown bark and dark purple-brown pear-shaped

fruit, *Ficus polita* Vahl., and *Chrysophyllum albidum* G. Don. with a milky juice, leaves dark green above and pale tawny below, and edible yellow-brown spherical fruit. The most abundant second-story tree is *Funtumia elastica* (Preuss) Stapf, the source of Lagos or West African rubber, while among the riot of shrubs and smaller trees occurs abundant wild coffee (*Coffea canephora* Pierre).[1]

Another depression forest occurs at Lotti towards the base of the Acholi Hills (Figs. 11 and 12). Among the trees forming the top canopy, of which the commonest is *Schrebera macrantha* Gilg. & Schellenb., may be seen

FIG. 11. Path through Lotti forest.

Alstonia congensis Engl., with its deeply fluted bole, chalky white latex, and seeds with a tuft of fluffy white hairs at each end, the huge *Entandrophragma macrophyllum* A. Chev., with a trunk up to 8 ft. in diameter above its buttresses, grey bark becoming scaly and long fruit containing seeds with long narrow wings up to 4 in. long, *Khaya grandifoliola* C. DC., *Chlorophora excelsa* Benth. & Hook. f., *Chrysophyllum albidum* G. Don., *Cola cordifolia* (Cav.) R. Br., while among the under-shrubs occurs wild coffee (*Coffea canephora* Pierre).

A third depression forest is found at Laboni in the Acholi Hills near the Sudan–Uganda border. The dominant top-story tree is *Chrysophyllum albidum* G. Don., which is the only dominant it shares with Lotti Forest; otherwise the forest is very different, especially in the larger variety of species and scarcity of mahogany (*Khaya grandifoliola* C. DC.) and *Chlorophora excelsa* Benth. & Hook. f. Wild coffee is an extremely abundant under-shrub.

[1] This is the *Coffea robusta* of authors and the 'robusta' coffee of commerce.—*Editor.*

(*c*) *Cloud Forests*. These forests occur at the higher altitudes of tropical mountains and are generally subject to prevailing mist and clouds while maintaining a moderate temperature. In the Sudan they are limited to the upper slopes of the Immatong and Dongotona Mountains, where occur forests of the conifers, *Podocarpus milanjianus* Rendle and *Podocarpus gracilior* Pilger. These will be mentioned under the description of the flora of Immatong and Dongotona Mountains.

7. *Swamps and Grasslands*

(*a*) *Permanent Swamps*. The principal constituents of the vast permanent swamps of the White Nile, known as the Sudd, are given under the section describing the White Nile.

Sedge swamps are found wherever a stream of any size has deposited sediment or has widened out between rapids. On the smaller rivers they may consist of edging to ponds or filling permanent wet depressions, but on the lower courses of the larger tributaries they may expand into vast areas of sudd. Papyrus (*Cyperus papyrus* Linn. var. *antiquorum* C. B. Clarke), with its often solitary stems up to 15 ft. high crowned with a head of fine rays up to 1 ft. long, is a dominant plant of these perennial swamps, and floating beds of the water grasses *Vossia cuspidata* Griff., with its knife-edged leaves up to 1½ in. broad, and towards the base of the stem having inside the leaves white irritating hairs, and the tall reed-like *Echinochloa pyramidalis* Hitchcook & Chase, with flowers in large dense heads, are often associated with it or form small swamps of their own. Among the sedges and grasses occur water-lilies and, in varying amount, most of the plants listed later as occurring along the White Nile.

(*b*) *Seasonally Inundated Land*. The bulk of the seasonally inundated land of the Sudan occurs along the White Nile and its tributaries forming the so-called 'toich' areas (Figs. 7 and 8). On these 'toich' areas the period of annual inundation, while long enough to inhibit tree growth, is not long enough to maintain permanent swamp conditions and to encourage sedges, so that for the whole of the long dry season the 'toich' form vast meadows of almost pure grass which maintain the very important Dinka and Nuer cattle industries.

These vast areas of water-meadows are interrupted by higher non-flooded islands where are found such woodland trees as *Acacia campylacantha* Hochst., *Acacia sieberiana* DC., *Celtis integrifolia* Lam., the thorny light-barked *Randia nilotica* Stapf, ebony (*Diospyros mespiliformis* Hochst.), *Combretum* spp., *Albizzia sericocephala* Benth., *Bauhinia* spp., 'heglīg', 'sidr' ('nabaq'), and occasional trees and sometimes pure stands of 'dolēb' palms, as well as the camps and cultivations of the cattle owners.

In general the 'toich' lands have rarely more than 1 ft. of water during the wet season save in ponds and water-courses. The soil on the surface is sandy and is underlain by a dark heavy clay which, with the absence of slope, presumably accounts for standing water during the wet season. The floristic composition of the grasses may vary somewhat. Broadly, however, the principal tall grasses are *Vetiveria nigritana* (Benth.) Stapf

FIG. 12. Lotti depression forest from Lotti rest-house: note elephant grass in foreground.

FIG. 13. Typical termite nest with *Zizyphus* sp. growing from it: typical of 'toich' land.

FIG. 14. Typical termite nest, older than that shown in Fig. 13 with, *Crataeva adansonii* DC. growing from it: typical of 'toich' land.

FIG. 15. Burned-over 'toich' land with *Acacia* sp. on large termite nest.

and *Sporobolus pyramidalis* Beauv., which form vast seas of almost pure stands, interrupted only by small trees on widely scattered high termite nests (Figs. 13, 14, and 15). Among these two tall grasses may occur *Sorghum lanceolatum* Stapf, around the smaller termite nests, and *Paspalum scrobiculatum* L. var. *polystachyum* Stapf, while in the wetter places *Setaria anceps* Stapf may become dominant. Other 'toich' areas may be covered with broad stretches of the tall grass *Loudetia superba* De Not, and the rice grass *Oryza barthii* A. Chev. may be locally abundant, while higher and drier ground may contain abundant *Hyparrhenia* spp.

Another important series of seasonally inundated land occurs along the Blue Nile, forming the so-called 'mayas' where forests principally of sunt occur. These have already been mentioned under the 'Acacia Tall Grass Forest Region' section.

(*c*) *Grassland.* Grassland *per se* is present only in negligible proportions in the Sudan. Excluding the 'toich' meadows mentioned above, and those produced artificially by deforestation or recently abandoned cultivations, grasslands, except for mountain meadows, only occur as short turf on rocky hills and plateau, and on ironstone pans which are sometimes large (Fig. 9). One of the commonest and most abundant grasses of those on shallows oil outcrops is the small open, often pink-headed *Sporobolus festivus* Hochst. Another prominent grass is the creeping annual *Digitaria longiflora* Pers., each with two or three very slender finger-like spikes of flowers, while another that is extensively dominant on ironstone pans is the erect *Loudetia annua* (Stapf) C. E. Hubbard up to 2 ft. high, with torch-like heads of flowers from which spring fine silky-white hairs. Among these dominant short grasses may be found a number of short herbaceous plants such as a yellow-flowered *Oxalis corniculata* L., the purple-flowered *Desmodium triflorum* (L.) DC., *Zornia diphylla* Pers. with its yellow, red-streaked flowers together with some small sedges, while among these may also occur less prominent grasses such as the perennial, stout *Chloris pilosa* Schum. & Thonn., the tufted *Eragrostis tremula* Hochst., with large heads of nodding clusters of flowers and the semi-creeping *Chloris pycnothrix* Trin.

(*d*) *Mountain Meadow.* Mountain meadows occur on shallow soil at the higher altitudes and while sustaining a high rainfall are subject to the increased humidity and lower temperatures induced by cloud and mist. These meadows are only prominent in the Sudan on the higher slopes of the Immatong and Dongotona Mountains. The herbs and grasses grow to a height of about 3 ft., and at a distance the meadows resemble the moorlands of English mountain scenery.

Of the grasses that commonly occur on these meadows, *Digitaria uniglumis* Stapf is probably the most prominent, while *Setaria sphacelata* Stapf & Hubbard, *Exotheca abyssinica* Anders are also important constituents. Among the herbs may be seen the beautiful, purple-to-blue-flowered iris, *Morea diversifolia* Baker, the purple-flowered *Justicia whytei* S. Moore, the yellow marigold, *Coreopsis tripartita* M. B. Moss, and the delightfully scented white-flowered *Delphinium candidum* Hemsl.

III. The Flora of Special Areas

1. *The Erkowit Plateau and Jebel Elba*

The Erkowit plateau, about 3,600 ft. high and situated about 24 miles east of Sinkat, is bounded on the north and east sides by a steep escarpment dropping almost 2,000 ft. to the plains and Red Sea. Its west and south sides merge into typical Red Sea Hills country. Jebels Nakeet and Es Sitt (Kitty's Leap), dropping steeply to Khor Dahand, mark the northern extremity of the plateau. On the other side of this khor is a barren range of hills of which the highest peak is J. Ungaibab. This range drops relatively steeply on the east to the Red Sea plain. On the south-eastern side the escarpment drops steeply to Khor Wintree, on the other side of which are the heavily covered evergreen slopes of the Deep range. Jebel Sela (4,244 ft.), the highest evergreen peak of the district, lies in the eastern portion of the plateau. Jebel Erbab (5,077 ft.) is a barren peak lying to the south of the Erkowit plateau.

The principal rains occur in the winter, though light showers may also occur during the summer. During the winter the hills are almost continuously covered by mist which blows up from the sea. A portion of the rain and mist blowing from the north-east meets no obstacle before impinging on the Erkowit escarpment and plateau. In consequence abundant evergreen vegetation which includes a number of Abyssinian species is maintained in this area and on the sides of the escarpment. West of the plateau, where the rain is caught by the intervening Red Sea Hills, only sparse vegetation of a drought-resisting kind is able to survive.

In consequence of this unequal distribution of available moisture the vegetation of the district can be divided into three principal zones:

(*a*) *An Arid Zone* lying to the west and south of the plateau.
(*b*) *A Transitional Zone* between (*a*) and (*c*).
(*c*) *A Moist Zone* consisting of eastern and north-eastern portion of the plateau.

(*a*) *Arid Zone* (Figs. 3 and 4). This zone includes the bulk of the scenery on the western boundaries of Erkowit and on the Sinkat road near Erkowit. It is dominated by the candelabra Euphorbia, *Euphorbia erythraeae* N. E. Br. and the dragon's blood tree *Dracaena Ombet* Kotschy & Peyr., with *Acacia etbaica* Schwfth. on the lower slopes and occasional 'heglīg' and 'sidr' ('nabaq') near the seasonal watercourses.

The under vegetation consists principally of the shrubby herbs, *Euphorbia thi* Schwfth., *Caralluma penicillata* N. E. Br., *Aloe abyssinica* Lam., with its heads of brilliant orange-red flowers, the yellow-flowered prickly Mexican poppy *Argenome mexicana* Linn., *Withania somnifera* Dun., with its scarlet berries, the spiny *Barleria* spp., the blue-flowered *Blepharis maderaspatensis* Heyne ex Roth. (= *B. boerhaaviaefolia* Pers.), and the false senna. Under extremely arid conditions, viz. on the sides of rocky hills, often only sparsely distributed *Euphorbia erythraeae* N. E. Br. and *Dracaena ombet* Kotschy & Peyr. persist, the latter often occurring where even *Euphorbia erythraeae* N.E. Br. is unhappy.

(*b*) *Transitional Zone*. In this zone, which is relatively narrow, *Dracaena*

ombet Kotschy & Peyr. is extremely rare and is replaced by *Gymosporia senegalensis* (Lam.) Loes., with its often maroon-coloured thorns, and more abundant 'samr', while *Euphorbia erythraeae* N. E. Br. maintains its dominance. As we proceed eastward, i.e. towards the moist zone, *Euphorbia erythraeae* N. E. Br. is rapidly replaced by the dominant shrub *Euclea kellau* Hochst., with its wavy leaves and purple edible berries, and other moist zone trees and shrubs. On the way to Jebel Yamerdermai the dominant vegetation is *Euphorbia erythraeae* N. E. Br. and *Gymnosporia senegalensis* (Lam.) Loes., with occasional *Acacia etbaica* Schwfth. The ebony (*Diospyros mespiliformis* Hochst.) and 'heglīg' are found near seasonal watercourses which frequently contain large trees of 'sidr' ('nabag'). 'Qammēz' (*Ficus sycomorus* Linn.) also occurs occasionally near these watercourses.

(*c*) *Moist Zone*. The moist zone lies towards the east of the plateau and includes the northern and eastern sides of the escarpment. *Gymnosporia senegalensis* (Lam.) Loes. and *Euclea kellau* Hochst. are dominant with frequent Erkowit privet (*Dodonea viscosa* Linn.) with its pale green shining leaves and winged fruit, *Rhus incana* Mill. (= *R. villosa* L. f.), the attractive sweet-smelling thorny Erkowit lilac (*Carissa edulis* Vahl), the ebony (*Diospyros mespiliformis* Hochst.), a curiously shrubby palm (*Phoenix* sp.), *Rhus abyssinica*, occasional thorny *Ximenia americana* Linn. with its yellow edible acid fruit, *Ficus glumosa* var. *glaberrima* Martelli, *Lannea schimperi* Engl., and infrequent specimens of the olive tree (*Olea chrysophylla* Lam.), except on Jebel Deep, where the olive is much more abundant. In the wettest portion *Euphorbia erythraeae* N. E. Br. and *Acacia* spp. are absent. The willow-like *Lachnopylis oppositifolius* Hochst. (= *Nuxia dentata* R. Br.) is often abundant, lining the watercourses of this zone. The undergrowth consists principally of the blue-flowered shrub, *Coleus barbatus* Benth., and various herbs. A few ferns occur in the shade of rocks. This type of vegetation is seen on Jebel Sitt, Maselli Pass, Korkali Pass, and intervening country, and the Jebel Deeb range.

Towards the moist zone in shallow valleys are small meadows with well-grazed grass and abundant specimens of the bulbous *Urginea micrantha* Solms.

Jebel Elba, lying about 200 miles to the north of Erkowit, has a very similar vegetation to that of the latter. Here, too, the luxuriant vegetation is said to be due to the absence of any considerable foot-hills between Jebel Elba and the sea. The sea mists thus come straight up against the cliff face without being dissipated on the way, and their entire moisture supply falls on the area immediately behind. Supporting this theory is the fact that, as at Erkowit, the north-east side of the Jebel, where there are no foot-hills, has much more luxuriant vegetation than the south-east side where a few foot-hills exist. A description of the flora of Jebel Elba would be similar to that of Erkowit.[1]

[1] For what it may be worth I suggest that the climate of Erkowit may be due to a happy combination of three things—latitude, situation, and elevation.

The latitude of 18° 45′ is so close to that of the edge of the desert at 19° 00′ that the trade winds blow from the north and north-east for the greater part of the year. The situation is on a westerly bend of the Red Sea coastline that exposes

2. *The Flora of the Blue Nile River, the Sennar Reservoir, and the Gezira Canals*

The Blue Nile river, as has been stated previously, is a rapidly flowing river, whose water plants are only able to thrive in the water of the seasonally inundated land along the banks. On this land the water is comparatively stagnant and therefore suitable for the growth of aquatic plants. Such an area of stagnant water exists in the Sennar Reservoir, an artificial lake about 80 kilometres long and up to 4½ kilometres broad, created by the Sennar Dam. In this reservoir are found most of the aquatic plants that occur in the seasonal ponds formed along the banks of the Blue Nile. The shore and islands of the reservoir are lined with the water grasses *Echinochloa stagnina* P. Beauv. and *Vossia cuspidata* Griff., while mixed with these grasses occurs a riot of smaller water plants which include the water lettuce (*Pistia stratiotes* Linn.), yellow- and white-flowered *Ottelia* spp., the insect-digesting *Utricularia* spp., blue and white water lilies, the purple-flowered *Ipomoea reptans* Poir, while almost pure stands of the smooth-leaved *Polygonum glabrum* Willd. and the hairy-leafed *Polygonum lanigerum* R. Br., with their heads of pink flowers, occur sparsely scattered among the water grasses. The flora is similar to that found in the White Nile but lacks its diversity of species.

It is to be expected that the Gezira canals whose water is derived from the Sennar Reservoir would be colonized by the aquatic plants of that reservoir. This, however, is not wholly the case, and aquatic plants occur in the canals that are not present in the reservoir, while the converse is also true.

The principal aquatic plants of the Gezira canals are the pondweeds, *Potamogeton perfoliatus* Linn., *P. nodosus* Poir, *P. crispus* Linn., and *P. pectinatus* Linn., the white-flowered *Ottelia alismoides* Pers., *Najas pectinata* (Parl) Magnus, and the grasses *Echinochloa stagnina* P. Beauv. and *Vossia cuspidata* Griff. Of these plants none of the pondweeds have been found in the Blue Nile river, while of the flora of the reservoir, *Pistia stratiotes* Linn., *Utricularia* spp., and water-lilies have not been found in the Gezira canals. There is as yet no satisfactory explanation for this discontinuity in aquatic plant distribution, but there is some slight evidence that the dam may act as a physical barrier.

3. *The White Nile from Khartoum to the Sudan Boundary*

The White Nile river, in contradistinction to the Blue Nile, is a relatively slow-flowing non-silt-carrying river. The reach from Khartoum

Erkowit to approximately 400 miles of open sea in a direction facing the trades. The elevation of the green zone is between 3,000 and 4,500 ft.

It is suggested that the dry trade winds from Arabia, passing over 400 miles of warm sea, pick up moisture that travels towards Erkowit at the 3,000- to 4,500-ft. level, and that on reaching the cool hills light cloud is formed and precipitation, mainly in the form of dew, occurs. Above and below this moisture-bearing air precipitation does not occur and one has the examples of the dry J. Erbab which is too high, and the equally dry foot-hills that are too low. At J. Elba some 200 miles to the north the same happy combination occurs of latitude, of situation on a westerly bend of the coastline, and of elevation at the level of the moisture-bearing stratum of air that has passed over about 400 miles of warm sea.—*Editor.*

FIG. 16. Erkowit plateau: moist zone: *Rhus abyssinica* Hochst. in immediate foreground.

FIG. 17. Shallow inlet, White Nile River, *Limnophytum obtusifolium* Mig. in foreground, and *Jussieua diffusa* Forsk. in middle-ground

FIG. 18. Shallow inlet, White Nile River, showing water-lilies (*Nymphaea lotus* Linn.), the water-lettuce (*Pistia stratiotes* Linn.), *Jussieua diffusa* Forsk., and the bulrush (*Typha angustifolia* Linn.) in right background.

FIG. 19. Papyrus islands grounded on river shore: White Nile River near Kosti.

to Kosti is in general bounded on the west side by shallow banks interrupted by inundated land where occur seasonally semi-submerged sunt trees. On the eastern side the banks are steeper and in the northern portion have frequent sand-dunes. At the water's edge occur sparsely scattered clumps of the water grasses *Vossia cuspidata* Griff., the more delicate *Echinochoa stagnina* P. Beauv. with its narrow leaves tapering to a fine point and rough when rubbed upwards, and the reed *Phragmites mauritianus* Kunth. with heads of fluffy flowers, the bulrush *Typha angustifolia* Linn., *Polygonum glabrum* Willd., with its heads of pink flowers, while the banks themselves are often lined with clumps of the creeping, purple-flowered *Ipomoea repens* Linn.

It is not until one reaches almost as far south as Kosti that papyrus (*Cyperus papyrus* Linn. var. *antiquorum* C. B. Cl.) begins to appear in any quantity (Fig. 19). The dominant water grass is still *Vossia cuspidata* Griff., while the shrubby prickly yellow-flowered ambatch (*Herminiera elaphroxylon* G. & P.) with its pods coiled like a watch-spring and swollen stems consisting of an extremely light pith-like substance, and *Aeschynomene* spp., with their yellow flowers and flat pods, occur in clumps.

From Kosti south (Figs. 17 and 18) the water flora consists principally of the water-lettuce (*Pistia stratiotes* Linn.), the white water-lily (*Nymphaea lotus* Linn.), the yellow-flowered *Jussieusa diffusa* Forsk. (Fig. 17) with its pale pink spindle-like floats, and *J. pilosa* H. B. & K., *Najas pectinata* (Parl) Magnus, the yellow-flowered *Ottelia ulvifolia* (Planch) Walp., and the white-flowered *O. alismoides* Pers., the little blue-flowered *Eichornia natans* Solms., the water fern *Azolla nilotica* Decne *ex* Mett., the hornwort (*Ceratophyllum dermersum* Linn.), *Utricularia* spp., and duckweed (*Lemna* spp.).

As we proceed upstream we pass at Malakal a large grove of 'dolēb' palms and south of Malakal we enter the so-called sudd area. Here papyrus increases in dominance and is associated with *Phragmites mauritanus* Kunth., *Vossia cuspidata* Griff., *Typha angustifolia* Linn., and *Echinochloa pyramidalis* Hitchcock & Chase. In this papyrus complex grow abundantly the yellow-flowered cosmea-like *Melanthera brownei* Schultz Bip., a purple-flowered *Ipomoea* sp., a pale cream, purple-centred flowered herbaceous climber *Oxystelma bornouense* R. Br., a fern *Dryopteris gongyloides* (Sehk.) O. Ktze., and a climber (*Cissus ibuensis* Hook. f.) with bunches of small inconspicuous flowers.

This sudd area of dominant papyrus continues to about half-way between Bor and Terrakekka and often extends several miles on either side of the free river.

From the end of the sudd area to the Sudan boundary the papyrus becomes less abundant and large stretches of the river are almost without it. Definite banks often line the river, and *Phragmites mauritanus* Kunth. again becomes dominant associated with *Vossia cuspidata* Griff., *Echinochloa pyramidalis* Hitchcock & Chase, and occasional trees where the bank is sufficiently high above the river.

4. *The Flora of the Immatong and Dongotona Mountains*

These mountains lying in the south-east corner are the most interesting botanically of the mountain massifs of the Sudan.

The Immatong Mountains containing the highest peak in the Sudan, viz. Mt. Kineti, 10,456 ft. high, are situated in a rising plain of medium grass mixed woodland. Ascending the mountain we pass through a belt of rather dense grass woodland containing Combretaceous trees and *Acacia seyal* Del. var. *multijuga* Schwf. At about 4,300 ft. bamboos begin to appear, while at 5,300 ft. we enter the conspicuously flat-topped *Acacia abyssinica* Hochst. zone (Fig. 22), which later replaces the Combretaceous

FIG. 20. Ascending the Immatong Mts.: note *Dracaena fragrans* Ker-Gawl in centre, and the wild banana, *Musa ensete* Gmel., in foreground.

trees and becomes the dominant woodland tree up to about 8,000 ft. The giant lobelia (*Lobelia giberroa* Hemsl.) appears at about 6,000 ft. (Fig. 21), while the small tree *Protea abyssinica* Willd., with its sunflower-like flowers surrounded by a dense undergrowth of small silvery silky leaves, becomes common at this height, later to be replaced by *Protea madiensis* Oliv. The bracken fern (*Pteridium aquilinum* Schott.), looking exactly like the bracken fern of England, begins to appear, and a little higher occurs a wild blackberry (*Rubus steudneri* Schweinf.). As we proceed upwards, mountain meadows become more frequent, bracken and blackberry become abundant, while at 9,000 ft. occurs a mountain bamboo (*Arundinaria*

FIG. 21. Giant lobelia (*Lobelia giberroa* Hemsl.), Immatong Mts.

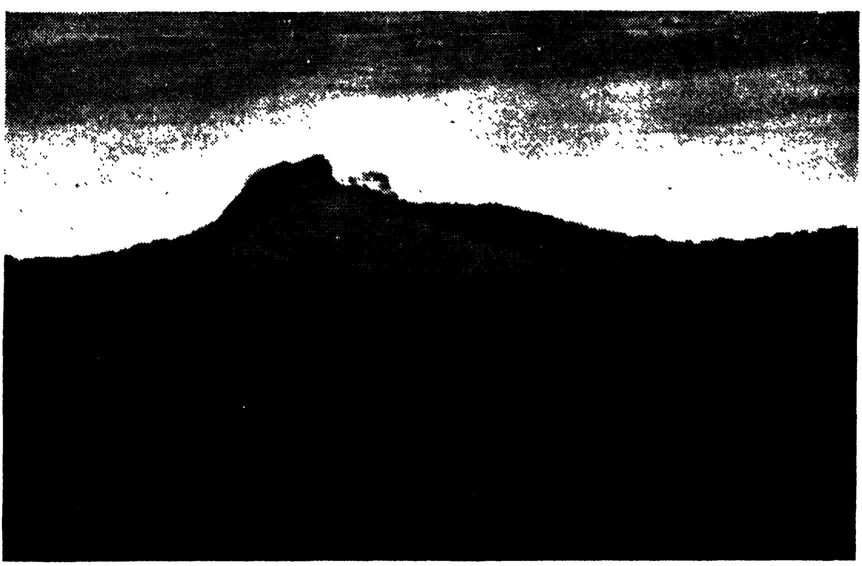


FIG. 22. Jebel Garia, Immatong Mts., showing typical flat-topped *Acacia abyssinica* Hochst., the dominant tree up to 8,000 ft.

sp.). The extensive gallery forests of the mountain ravines from 7,000 to 10,000 ft. consist principally of the conifer *Podocarpus milanjianus* Rendle. Along the borders of these forests occur shrubby vegetation containing the yellow-flowered succulent *Kalanchoe petitiana* A. Rich., the white-flowered *Cyathula schimperiana* Mog., the yellow-flowered *Cineraria kilimanscharica* Engl., while the 7-ft. grass *Hyparrhenia cymbaria* Stapf lines the edge of the forest. From 9,000 ft. a dense growth of prickly scrub is seen which ceases just before meeting the crest of Mt. Kineti (10,456 ft.) and is succeeded by a short springy turf. The woody species which approach nearest to the exposed top of the mountain are *Hypericum lanceolatum* Lam., with masses of large yellow flowers, the heath-like *Anthospermum usambarense* K. Sch., and *Brayera anthelmintica* Kth., with pink flaps to its leaf stalks. The mountain-top itself is covered with short grass and herbs protected by rocky outcrops. The herbs include the snowy-white *Helichrysum argyranthum* O. Hoffm. and the yellow *Helichrysum fruticosum* Vatke, the bright blue-flowered *Lobelia dissecta* M. B. Moss, an *Asparagus* sp., a stemless thistle (*Carduus theodori* R. E. Fries), and the yellow-flowered bushy *Coreopsis chippii* M. B. Moss.

The Dongotona Mountains lying to the east of the Immatong Mountains and in a more arid district are not so high as the latter, reaching only to about 8,300 ft. Similar vegetation, however, occurs on their upper slopes. At about 5,900 ft. we find the bracken fern and the giant lobelia, and at 6,500 ft. we reach the Podocarpus forests with the olive *Olea welwitschii* (Knobl.) Gilg. & Schellenb., becoming more frequent as we ascend, while the related olive *Olea hochstetteri* Baker is also seen. Both *Podocarpus milanjianus* Rendle and *P. gracilior* Pilger are found in the upper forests, while *Teclea* sp. and *Dracaena afromontana* Mildbraed form an open undergrowth.

IV. List of Some Common Trees, Shrubs, and Herbs mentioned in this Chapter the Botanical Names of which are Incorrectly Given in Broun and Massey's 'Flora of the Sudan'

Arabic name	*Correct Botanical name*	*Botanical name in Broun and Massey*
Adlīb	*Suaeda monoica* Forsk.	*S. fruticosa* Forsk.
Arrāda	*Albizzia seriococephala* Benth.	*A. amara* Boivin.
Dahassir	*Indigofera oblongifolia* Forsk.	*I. paucifolia* Del.
Dolēb palm	*Borassus aethiopium* Mart.	*B. flabbelifer* Linn. var. *aethiopium* Warb.
Hashāb	*Acacia senegal* Willd.	*A. verek* G.P.
Haskanīt	*Cenchrus biflorus* Roxb.	*C. catharticus* Del.
Kadada	*Dichrostachys glomerata* Choiv.	*D. nutans* Benth.
Kakamūt	*Acacia campylacantha* Hochst.	*A. suma* Kurz.
Kūk	*Acacia sieberiana* DC.	*A. verugera* Schwfth.
La'ōt	*Acacia orfota* (Forsk.) Schweinf.	*A. nubica* Benth.
Lulu	*Butyrospermum niloticum* Kotschy	*B. parkii* Kotschy var. *niloticum* Kotschy
Mokhēt	*Boscia senegalensis* (Pers.) Lam.	*B. octandra* Hochst.
Sahab	*Anogeissus Schimperi* Hochst.	*A. leiocarpus* G. and P.

Arabic name	*Correct Botanical name*	*Botanical name in Broun and Massey*
Sala'alaa	*Cissus quadrangulus* Linn.	*C. quadrangularis* Linn.
Sallam	*Acacia flava* (Forsk.) Schweinf.	*A. ehrenbergiana* Hayne
Samr	*Acacia tortilis* (Forsk.) Christensen	**A. spirocarpa* Hochst.
Senna (false)	*Cassia ashrek* Forsk.	*Cassia obovata* Collad.
Seyal	*Acacia raddiana* Savi.	**A. tortilis* Hayne

* The names of *A. spirocarpa* Hochst. and *A. tortilis* Hayne in Broun and Massey should be interchanged.

V. Acknowledgements

In the preparation of this general account of the vegetation of the Sudan I have consulted Dr. J. D. Tothill's notes on the vegetation of Darfur Province, Mr. R. D. Maxwell-Darling's 'The Solitary Phase of *Schistocerca gregaria* Forsk., in N. E. Kordofan' for information on the vegetation of that district, Mr. J. R. Thomson's note on 'The Ecology and Agriculture of the Dinder Gezira', the late Dr. Chipp's account of 'The Immatong Mountains, Sudan'; but in particular I have quoted extensively from the notes prepared by the late Dr. J. G. Myers while making an ecological survey of Equatoria Province.

The principal divisions of the vegetation of the Sudan were decided after consultation with Mr. John Smith, Chief Conservator of Forests, Sudan Government.

CHAPTER V

THE CLIMATE OF THE SUDAN

By A. W. IRELAND, B.SC., A.INST.P., F.R.MET.SOC.
Sudan Government Meteorologist

'The weather is beautiful; but as Noodle says (with his eyes beaming with delight), we shall suffer for this, Sir, by and by.'
SYDNEY SMITH, Letter to Sir George Phillipp, Dec. 1836.

THE climate of a region is determined by two things: the air-masses which flow over it and its topography and geographical position. These are, in a sense, interdependent but are more conveniently dealt with separately.

An air-mass is an extensive body of air within which such properties as temperature and humidity vary little at a given level. Such a body originates at a source-region, a large area with uniform surface conditions over which the air remains long enough to acquire approximate homogeneity. As an air-mass moves away from its source-region its properties are gradually modified, particularly in the lower layers, but they remain characteristic for a considerable time. Primary source-regions are usually regions of permanent or semi-permanent high pressure, the tropical and polar high-pressure systems providing many of the principal air-masses of the world. There are also secondary source-regions, which produce less extensive and homogeneous air-masses but are of considerable local importance. In general a continental or land source provides a dry air-mass with extremes of temperature, either hot or cold according to the latitude and the season, whilst a maritime or oceanic source provides a moist one without such temperature extremes.

The movements of air-masses are controlled by the pressure and temperature fields, that is by the distribution of regions of high and low pressure and temperature. In the northern hemisphere they tend to move in a clockwise sense round regions of high pressure or temperature and in an anti-clockwise sense round lows, and vice versa in the southern hemisphere.

The pressure field over the surface of the earth shows certain permanent characteristics which determine the general nature of air-masses and their circulation. The poles and tropics are regions of high pressure separated by the temperate and equatorial lows. The resultant generalized circulation is shown in the diagram on p. 63. The zones depicted above have a seasonal movement north and south with the sun. They are also modified considerably near or over land-masses.

The air-masses affecting a particular region are determined by its position relative to this general circulation or, in other words, by its geographical position, and its climate depends upon the characteristics of these air-masses and the way in which they change during the year.

The climatic pattern so determined by the geographical position upon broad air-mass considerations is modified locally by other geographical and topographical factors. The duration and intensity of the sun's radia-

tion varies with the latitude, and to a lesser extent with the altitude. Seas, lakes, and other water surfaces have a considerable local effect, as have hills and mountain ranges; and the type of soil or vegetation may be important.

Rain is one of the most important meteorological elements from the agricultural point of view. When air ascends it cools, and eventually its moisture-content condenses to form cloud. Under certain conditions the tiny drops of water which constitute a cloud combine to form larger drops,

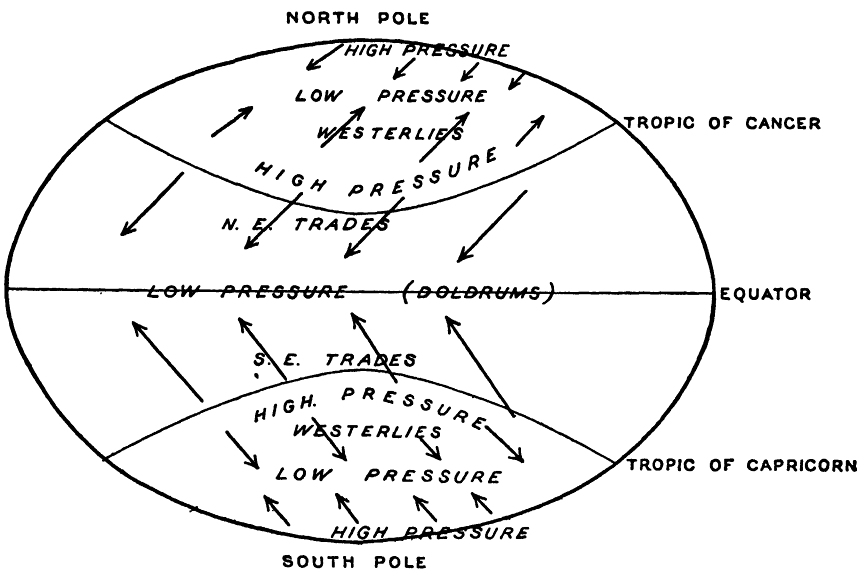


FIG. 23. This diagram presents a generalized picture of the circulation of air over the globe.

which fall as rain. Air may be made to ascend in several different ways and rain is classified accordingly.

Convectional rain occurs when the air near the ground is heated, expands, and rises through its denser environment. Afternoon thunderstorms are typical manifestations of convective activity.

Air may also be forced to ascend by passage over high ground. Rain produced in this way is called orographic rain.

Finally, at the boundary, or front, between two air-masses, the warmer of them may rise over the colder, and therefore denser, and yield cyclonic or frontal rain.

The Sudan lies wholly within the tropics, between latitudes 22° and 3° N., and its topography is from the meteorological point of view simple. It is almost entirely land-locked and has a predominantly continental climate. The Red Sea introduces certain maritime characteristics, but these are confined to the narrow coastal plain and the eastern slopes of the Red Sea Hills. Broadly speaking the country is one vast plain, broken only by the Marra Mountains of Darfur and the Nuba Mountains of southern Kordofan. Except in the sudd region, where there are extensive

swamps, there are no lakes or inland water surfaces large enough to produce even local climatic effects. To the west and north the plain extends far beyond the frontier, and to the east and south it is limited by the Ethiopian plateau and the higher ground of East Africa and the Belgian Congo.

The seasonal and latitudinal variation in the duration of daylight is shown in Fig. 23*a*.

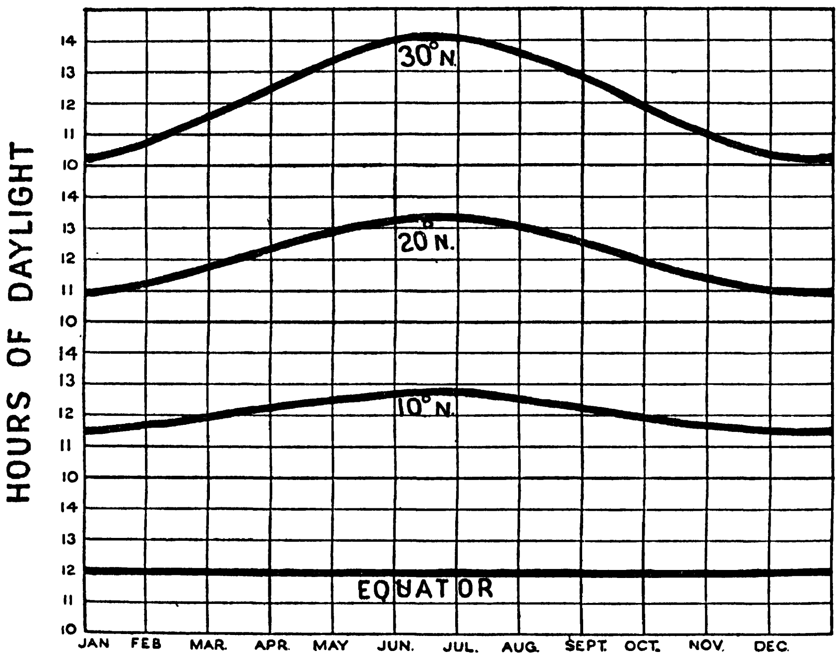


FIG. 23*a*. This diagram shows graphically for various latitudes the variation throughout the year of the daily duration of daylight.

Fig. 24 shows the mean flow in the surface layers of the atmosphere in January, April, July, and October. They are based upon wind observations up to 10,000 ft. above the surface.

Two main flows can be distinguished, one originating in the north and the other in the south. They may be called respectively the northerlies and the southerlies. These terms are used to indicate where the air originates, and not the actual direction in which it flows at any particular place.

The northerlies correspond to the trade winds of oceanic regions but are much less uniform in character, the vast land-masses to the north causing large seasonal variations in the pressure and temperature fields. These variations are such that the northerlies may be subdivided into several different and distinct types. In winter the Saharan high-pressure system dominates the circulation and the northerlies are mainly of a cool dry continental nature from the North African source-region, though

occasionally the Arabian high intensifies and brings a rather warmer air-mass to the eastern part of the country. Both of these types are periodically cut off by the passage of depressions from west to east along the Mediterranean and replaced by cold dry continental air from the Eurasian

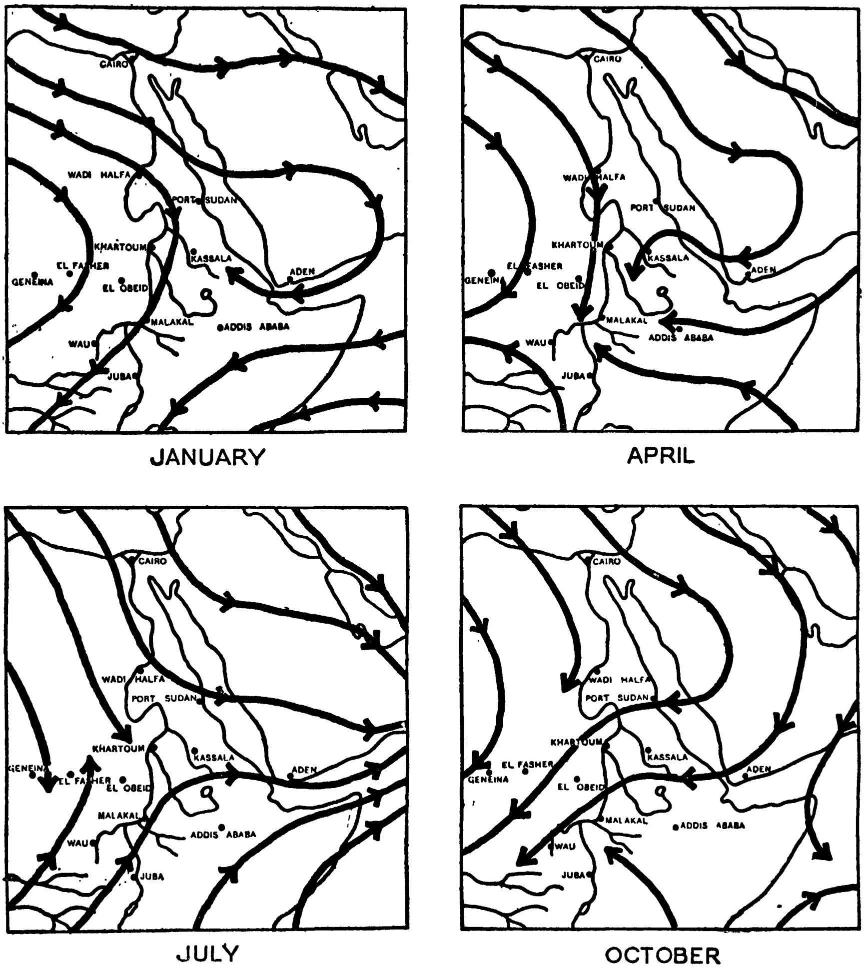
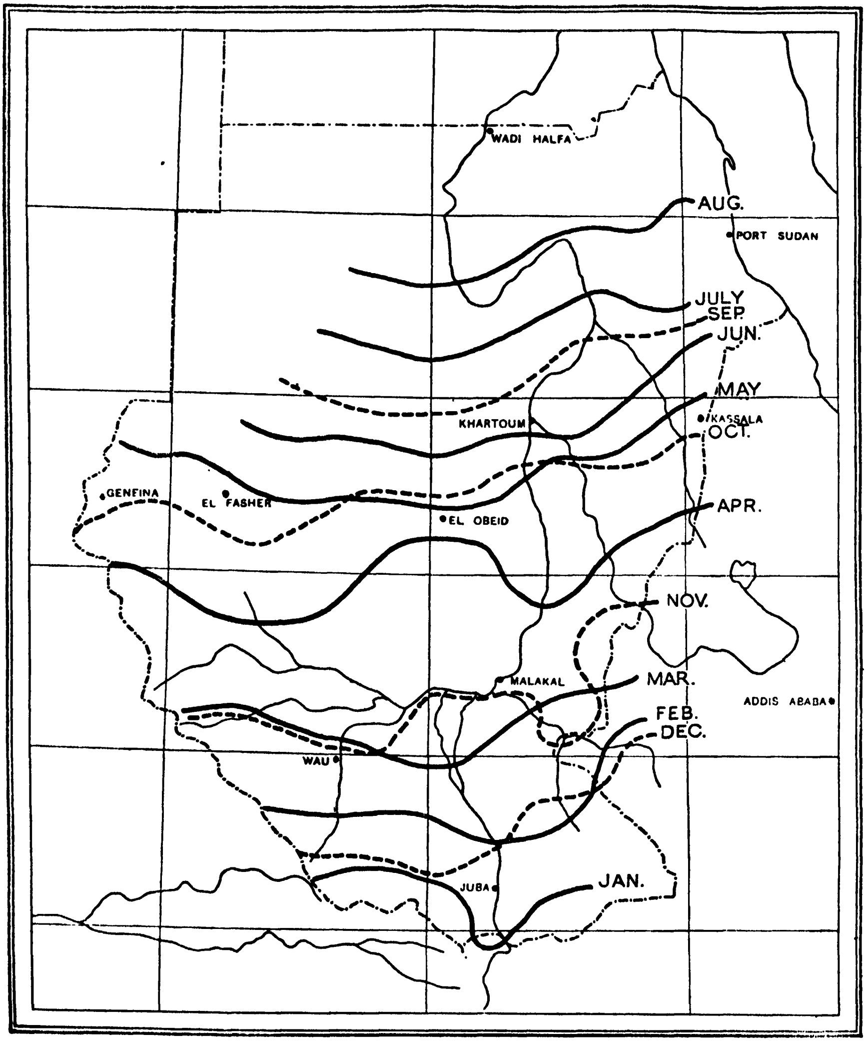


FIG. 24. These maps represent diagrammatically the mean flow in the surface layers of the atmosphere during January, April, July, and October. They have been derived from upper wind observations up to 10,000 ft. above the surface.

land-mass. In spring and autumn the Arabian high is more dominant in the east and the effect of Mediterranean depressions is rarely felt as far south as the Sudan. From both the North African and the Arabian sources the air is in these seasons considerably warmer than in winter. In summer the Arabian high disappears completely and the Saharan high is again dominant, bringing hot dry air. All the northerly air-masses are dry, and usually extremely so, not only because of their continental origin



MEAN 10MM. ISOHYET
(TO 1940)

FIG. 25. This map shows the mean 10-mm. isohyet, or line of equal rainfall, for each month of the year. It illustrates the regular annual advance and retreat of the rainy season.

but also because they subside, or descend from higher altitudes, as they move south. At times the maritime influence of the Mediterranean is felt in the Sudan, but that of the Red Sea, though of considerable local importance near the coast, is negligible inland.

The southerlies are much more uniform than the northerlies, and no satisfactory subdivisions are normally possible. The southern hemisphere tropical highs over the Indian and the Atlantic Oceans are the original sources, but the long slow passage over Central Africa removes most of the characteristics which would enable a clear distinction to be made. Whatever their origin, however, the southerlies are still primarily maritime when they reach the Sudan, and bring rain.

The dominant feature of the climate of the Sudan is the movement north and south with the declination of the sun of the boundary between the northerlies and the southerlies, which lies along the equatorial low-pressure belt, the oceanic Doldrum region. The mean position of this boundary during a particular month corresponds closely to the 10-mm. isohyet, and the nature of its annual movement is indicated in Fig. 25, which shows this isohyet for each month of the year.

Climatically the Sudan may be divided into three regions:

1. North of about latitude 19° N.
2. South of about latitude 19° N.
3. The Red Sea coast and the eastern slopes of the Red Sea Hills.

The main characteristics of the climate in each of these regions are summarized below.

North of about latitude 19° N.

This is a desert region where the dry northerlies prevail throughout the year and rain is infrequent. In winter strong winds, sandstorms, and occasionally frontal rain occur when there is an influx of cold air behind a vigorous Mediterranean depression. It experiences the large diurnal and annual variations in temperature characteristic of a desert climate.

South of about latitude 19° N.

In this region the climate is of a typical tropical continental type and dominated by the annual movement of the boundary between the dry northerlies and the moist southerlies. This boundary reaches its northerly limit in midsummer and its southerly limit in midwinter. Rain is associated with the southerlies, and particularly with the zone extending 500 miles or so south from the actual boundary. The rainy season is therefore shortest in the north and longest in the south. Only the extreme south emerges from the southern limit of the zone of maximum rain and shows the equatorial double rainfall maximum. Most of the rain is convectional and has a marked diurnal maximum in the afternoon and evening.

The weather is very stable during the dry winter season but intense thunderstorms occur in summer. In the northern part of the region, which is semi-arid and has little binding vegetation, particularly early in the rainy season, the strong winds associated with these summer thunderstorms cause dust-storms, locally called 'habūb'. This name is derived

from the Arabic verb 'to blow' and is often also used for dust- or sand-storms of an entirely different type which occur in winter, and are similar to those described in the section on the region north of latitude 19° N.

The Red Sea coast and the eastern slopes of the Red Sea Hills

In this region, as in the region north of about latitude 19° N., the northerlies prevail throughout the year, but the climate is profoundly modified by the maritime influence of the Red Sea. After a long passage over this sea, whose waters are hot at all seasons, the lower layers of the dry continental northerlies absorb a considerable amount of moisture, and rain and cloud develop. This rain is partly convectional and partly orographic, the proportion of the latter increasing inland as the coastal plain merges into the Red Sea Hills. After an overland or short sea passage the northerlies retain their dry continental characteristics and rain is infrequent. Rain is possible at any time of the year, but most of it falls during the winter, when the necessary long sea passage is most common.

Sea breezes occur along the coast between May and October with a fairly well-defined onset at about 0900 hrs. local time.

The weather in the Tokar area is considerably influenced by local topographical peculiarities. In summer the southerlies, to which elsewhere the Red Sea Hills are an effective barrier, sometimes penetrate the Baraka gap. Also the fine silt of the Baraka delta is readily picked up by the wind and severe dust-storms are experienced at all seasons. These storms are most intense and frequent in summer, when convective activity is greatest and incursions of the southerlies are experienced.

Tables and Maps

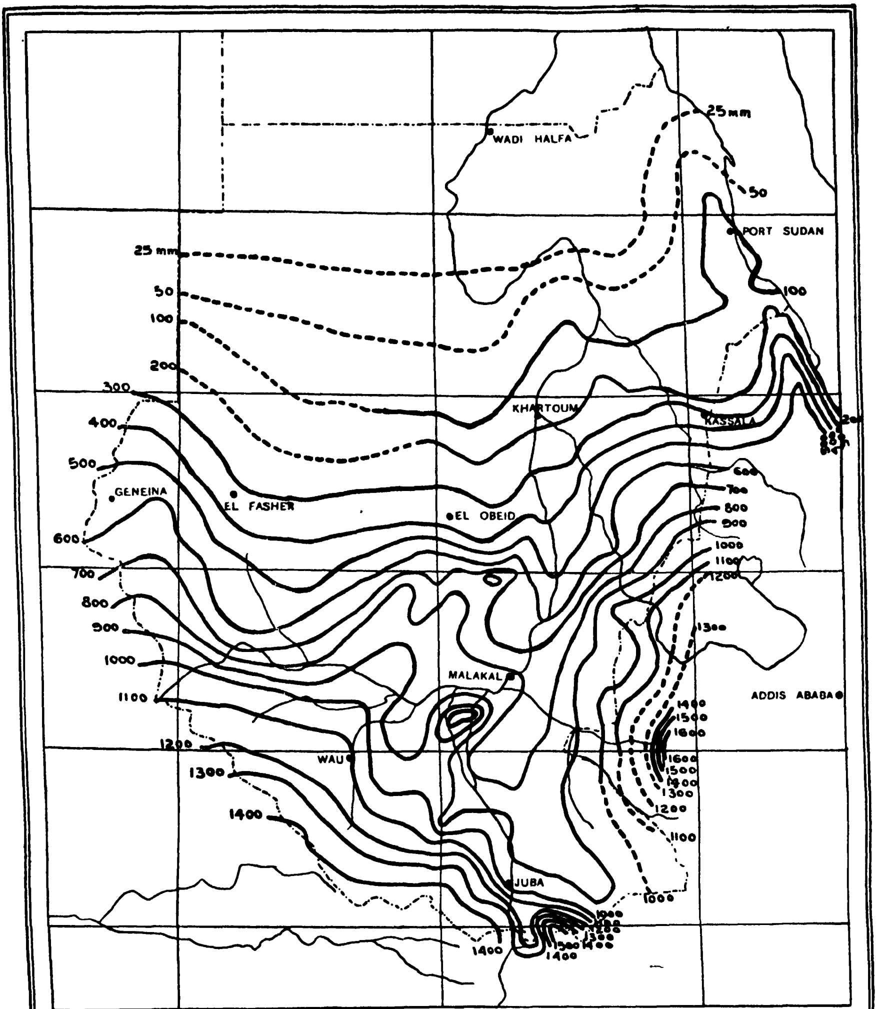
Tables and maps are appended. In every case the mean is the arithmetic mean.

Degrees Centigrade may be converted into degrees Fahrenheit by multiplying by the factor 1·8 and adding 32. Millimetres may be converted into inches by multiplying by the approximate factor 0·4.

Acknowledgements

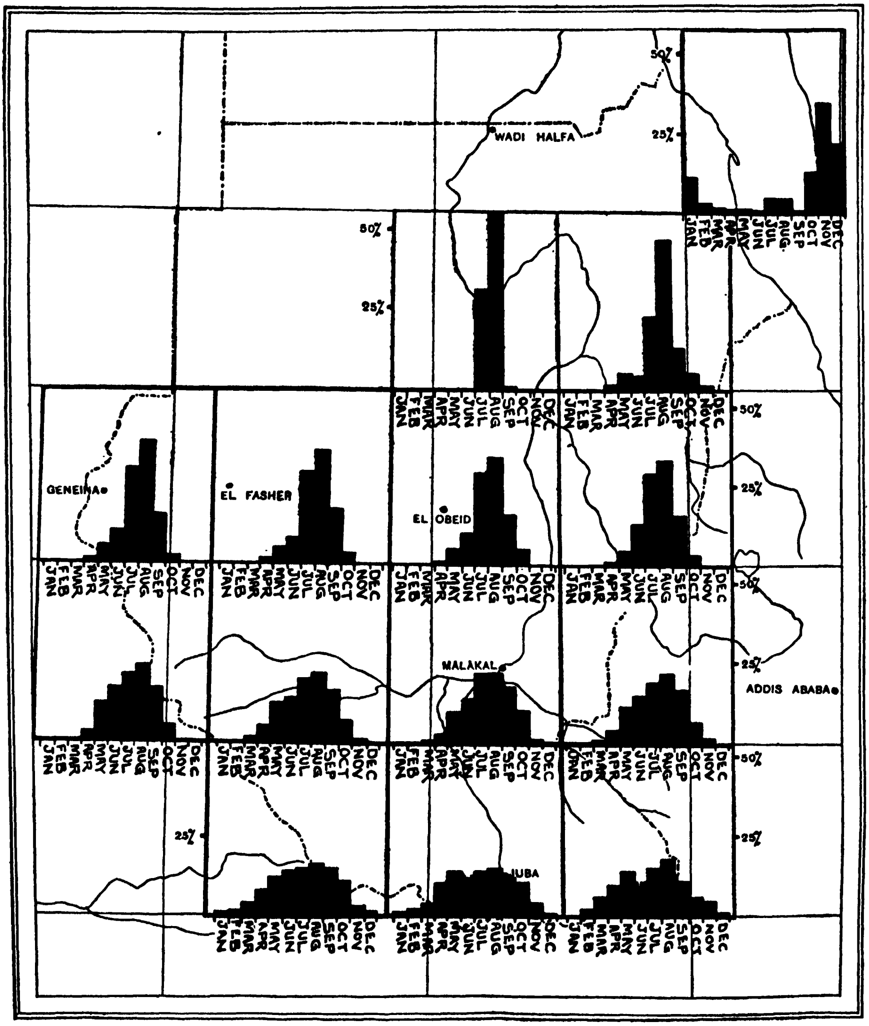
In preparing a paper of this kind observations made by other meteorological organizations have inevitably been used, explicitly or implicitly, and individual acknowledgements are impossible. Particular thanks are due, however, to the Physical Department of Egypt, the Meteorological Service of which, under the direction of Mr. L. T. Sutton, was responsible for the meteorological organization in the Sudan until 1936, and under whose auspices almost all previous work on the meteorology of the Sudan has been published. In addition to these publications I have used extensively unpublished data supplied by the Department which willingly undertook the additional laborious abstraction and computation involved.

I wish also gratefully to record my appreciation of the work of Mr. W. D. Flower, late Sudan Government Meteorologist, who founded the Sudan Meteorological Service as a separate organization and had done much of the preliminary work for this chapter at the time of his death in September 1942.



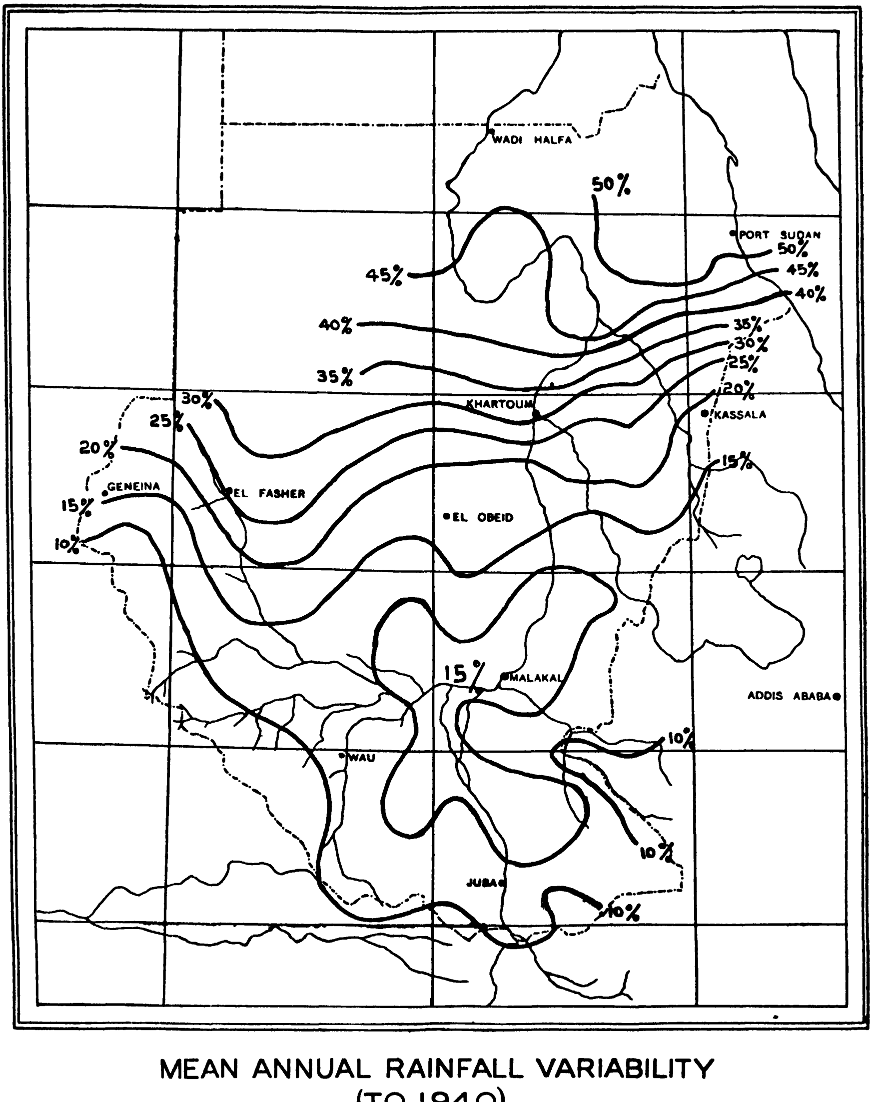
MEAN ANNUAL RAINFALL (MM)
(TO 1940)

FIG. 26. This map shows mean annual isohyets. The decrease in the rainfall from south to north is remarkably regular. The deformation produced by the Marra and Nuba Mountains and the Ethiopian Plateau is clear. The map probably under-estimates the local effect of the Marra Mountains for which no observations are available. The reason for the curious deformity south-west of Malakal is not obvious. Unfortunately it is based upon one station only and may not be real. Tentative explanations are that the swampy sudd region has a local effect, or that it is connected in some way with the Rudolf gap between the Ethiopian plateau and the East African highlands.



MEAN ANNUAL RAINFALL DISTRIBUTION
(TO 1940)

FIG. 27. This map shows the distribution of rainfall over the year expressed as percentages of the annual total falling in each month. Except in the coastal area the diagrams represent means over 4-degree squares. The increase from north to south in the length of the rainy season inland and the anomalous régime in the Red Sea area are clear. The latitudinal uniformity is notable. In the extreme south the equatorial double maximum can just be detected.



MEAN ANNUAL RAINFALL VARIABILITY
(TO 1940)

FIG. 28. The variability or reliability of the rainfall is of particular agricultural importance in semi-arid regions where cultivation is marginal. For this map a conventional numerical expression for this variability has been calculated. The deviations of actual annual totals from the mean have been summed irrespective of sign, meaned and expressed as a percentage of the mean annual total. Roughly a variability of 30 per cent. calculated in this way indicates that an actual total is as likely as not to differ by 30 per cent. from the mean.

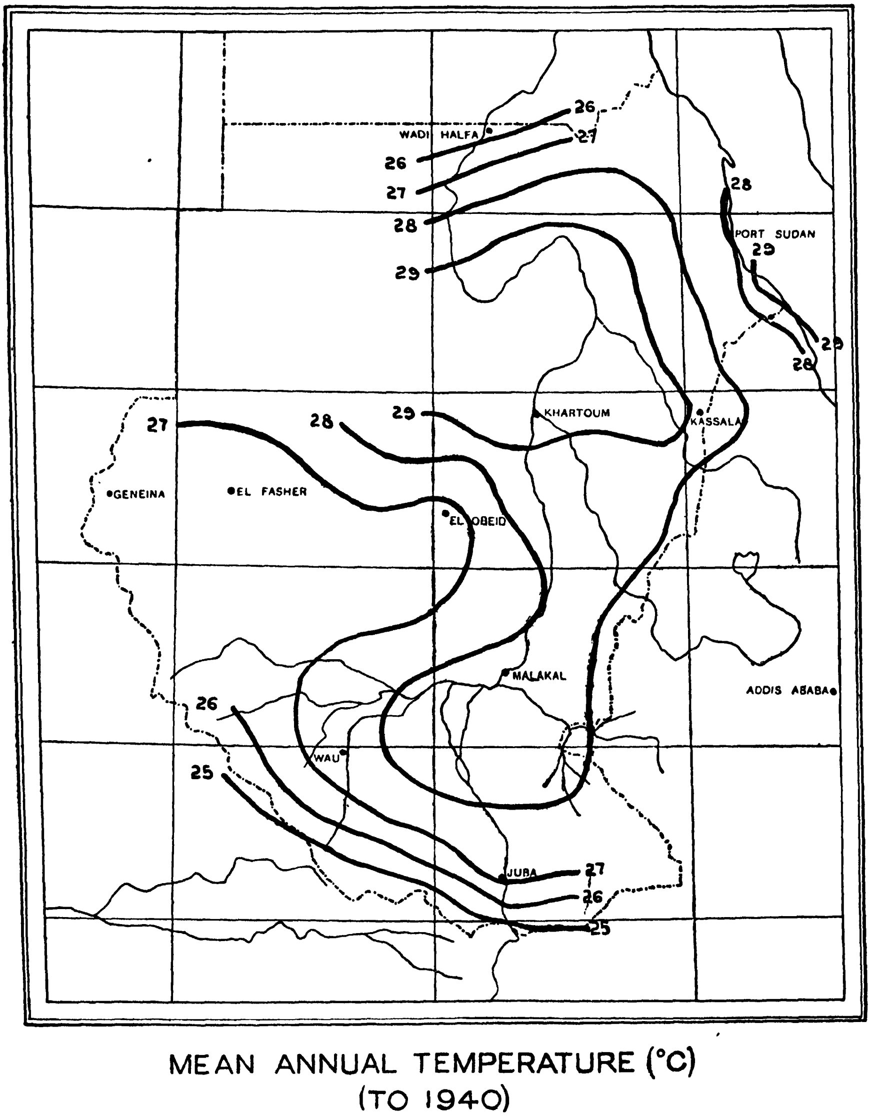


FIG. 29. This map shows mean annual isotherms, or lines of equal temperature. The temperatures are not reduced to a standard level. The network of temperature observations is tenuous and in certain areas the isotherms should be accepted with reserve.

TABLE 1. *Particulars of certain Stations in the Anglo-Egyptian Sudan*

Station	*Period*	*Latitude*	*Longitude*	*Altitude (metres)*
Atbara	1902–40	17° 42′	33° 58′	345
Karīma	1905–40	18° 33′	31° 51′	250
Wadi Halfa	1902–40	21° 55′	31° 20′	125
Jebel Aulia	1920–40	15° 14′	32° 30′	380
Khartoum S.L.	1900–40	15° 37′	32° 32′	380
Aroma	1925–40	15° 50′	36° 09′	430
Gallabat	1905–40	12° 58′	36° 10′	760
Gebeit	1916–40	18° 57′	36° 50′	795
Kassala	1901–40	15° 28′	36° 24′	500
Port Sudan	1905–40	19° 37′	37° 13′	5
Tokar	1913–40	18° 26′	37° 44′	20
Ed Dueim	1902–40	14° 00′	32° 20′	380
Hag 'Abdullah	1930–40	13° 57′	33° 34′	415
Rabak	1938–40	13° 11′	32° 43′	385
Er Roseires	1904–40	11° 51′	34° 23′	465
Sennar	1922–40	13° 33′	33° 37′	420
Singa	1912–40	13° 09′	33° 57′	430
Wad Medani G.R.F.	1919–40	14° 24′	33° 29′	405
Wad Sha'ir	1929–40	14° 42′	33° 17′	400
Wad et Turabi	1930–40	15° 05′	33° 03′	390
En Nahud	1938–40	12° 42′	28° 26′	565
El Obeid	1901–40	13° 11′	30° 14′	565
El Fasher	1918–40	13° 38′	25° 21′	740
Geneina	1938–40	13° 29′	22° 27′	805
Akobo	1932–40	07° 47′	33° 01′	400
Gambela	1909–40	08° 15′	34° 35′	450
Malakal	1915–40	09° 33′	31° 39′	390
Malek	1931–39	06° 04′	31° 36′	420
Renk	1938–40	11° 45′	32° 47′	380
Juba	1915–40	04° 51′	31° 37′	460
Loka	1929–40	04° 22′	30° 57′	965
Raga	1928–40	08° 28′	25° 41′	460
Sources Yubo	1928–40	05° 24′	27° 15′	600
Torit	1922–40	04° 25′	32° 33′	625
Wau	1902–40	07° 42′	28° 01′	435

The geographical co-ordinates and altitudes in 1940, and the periods during which meteorological observations have been made, are given for a selection of stations. At certain of them rainfall observations only, all of which have been used, have been made for longer periods. The stations are arranged alphabetically by provinces.

TABLE 2. *Mean Daily Maximum Temperature at certain Stations in the Anglo-Egyptian Sudan (in ° C.)*

Extremes are indicated in heavy type

Station	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Atbara	30.3	32.0	35.7	39.7	41.9	**42.8**	40.6	39.7	41.0	39.4	35.1	31.6	37.5
Karima	29.6	31.2	35.4	39.7	42.7	**43.8**	42.3	41.7	42.6	40.6	35.1	30.8	38.0
Wadi Halfa	24.0	26.3	31.3	36.4	39.9	**41.3**	41.1	40.6	38.6	36.7	30.8	25.6	34.4
Jebel Aulia	31.0	33.0	36.5	40.0	**41.1**	40.3	36.7	34.4	37.0	38.6	34.6	31.8	36.2
Khartoum S.L.	32.1	33.8	37.7	40.9	**41.9**	41.1	38.5	36.7	39.3	40.2	36.5	33.3	37.7
Aroma	33.0	34.8	37.6	41.4	**42.0**	40.7	36.7	35.2	37.2	39.5	36.8	34.4	37.4
Gallabat	36.0	37.0	38.7	**39.4**	37.6	33.5	29.6	29.3	30.9	34.0	35.8	35.7	34.8
Gebeit	24.1	24.8	28.0	31.6	35.1	**38.5**	38.1	37.1	37.2	32.3	28.0	25.3	31.7
Kassala	34.0	35.6	38.3	40.7	**41.2**	39.4	35.2	33.6	36.3	38.9	37.5	34.9	37.1
Port Sudan	27.1	27.2	28.7	31.6	35.1	38.9	**40.9**	40.7	37.9	33.9	31.1	28.5	33.5
Tokar	28.7	28.9	31.1	33.8	38.4	42.1	**42.5**	41.5	40.9	36.3	33.0	30.1	35.6
Ed Dueim	33.0	34.8	38.0	**40.9**	**40.9**	39.5	36.0	34.2	36.3	38.9	36.9	33.8	36.9
Hag 'Abdullah	34.3	35.8	38.7	**41.0**	40.6	38.5	34.5	32.5	34.6	38.1	36.8	34.8	36.7
Rabak	33.7	35.2	36.7	**40.6**	39.3	37.5	33.6	31.3	33.9	37.2	35.8	34.9	35.8
Er Roseires	36.5	37.8	39.8	**40.8**	38.7	35.2	32.4	31.9	33.2	36.0	37.5	36.7	36.4
Sennar	34.9	36.4	39.7	**41.9**	41.0	39.0	35.0	33.3	35.0	38.3	37.8	35.7	37.3
Singa	35.1	36.5	39.6	**41.4**	40.1	37.6	33.8	32.2	34.1	37.6	37.8	35.7	36.8
Wad Medani G.R.F.	34.1	35.4	38.6	**41.2**	**41.2**	39.5	35.6	33.6	35.8	38.6	37.0	34.6	37.1
Wad Sha'ir	32.8	34.9	37.8	40.6	**40.9**	39.4	35.7	33.2	35.6	38.2	35.6	33.6	36.5
Wad et Turabi	32.7	34.3	37.3	40.6	**41.5**	40.1	36.6	34.4	36.9	39.1	35.8	33.1	36.9
En Nahud	31.9	33.5	34.7	**39.3**	38.5	36.7	32.8	31.8	33.8	35.9	33.0	32.8	34.6
El Obeid	30.4	32.4	35.7	38.7	**39.1**	37.5	34.1	32.6	34.6	36.6	34.3	31.4	34.8
El Fasher	31.3	33.1	36.4	39.0	**39.5**	39.1	35.8	33.6	36.1	37.3	34.5	32.0	35.6
Geneina	33.9	35.8	36.4	**39.3**	**39.3**	38.1	33.6	31.2	33.5	36.1	34.4	34.3	35.5
Akobo	36.6	37.7	**38.5**	37.1	34.0	32.8	31.2	31.0	31.8	33.1	35.1	35.7	34.6
Gambela	36.8	37.6	**38.5**	36.8	33.6	31.8	30.7	30.8	31.7	33.4	34.6	35.8	34.3
Malakal	35.7	37.2	**39.1**	38.6	36.0	33.0	31.2	31.1	32.4	34.0	35.7	35.8	35.0
Malek	36.7	**36.9**	**36.9**	35.1	33.1	31.8	30.9	30.6	31.5	33.1	35.0	35.7	33.9
Renk	34.3	36.0	37.9	**40.3**	38.5	35.4	32.2	30.8	32.7	36.2	36.4	35.9	35.5
Juba	37.4	**37.7**	37.1	35.6	33.5	32.5	31.1	31.3	32.8	34.2	35.5	36.4	34.6
Loka	**33.5**	33.3	32.6	30.8	29.7	28.9	27.5	28.0	29.0	29.8	31.4	32.3	30.6
Raga	35.6	37.0	**38.0**	37.2	35.2	33.1	31.1	30.8	32.0	33.6	35.1	35.3	34.5
Sources Yubo	32.9	**33.2**	32.6	30.8	30.0	28.6	27.6	28.0	29.0	29.8	31.2	32.3	30.5
Torit	**37.7**	37.4	36.5	35.5	33.5	32.3	30.5	30.8	32.9	34.1	35.6	35.6	34.4
Wau	35.8	36.8	**37.9**	37.1	35.0	33.2	31.7	31.4	32.7	34.1	35.5	35.8	34.8

In the north and the Red Sea area the highest mean maxima occur in June or July. Elsewhere they precede the rains and the months of occurrence vary from May in the latitude of Khartoum to January in the far south. The lowest mean maxima occur in January in the north and in July or August, during the rainy season, south of about latitude 14° N. The seasonal variation decreases from north to south.

TABLE 3. *Highest Maximum Temperature at certain Stations in the Anglo-Egyptian Sudan (in ° C.)*

Extremes are indicated in heavy type

Station	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Atbara	38·6	42·0	44·3	46·0	47·0	**47·7**	45·5	47·0	45·0	44·0	41·5	40·7	47·7
Karima	40·5	42·5	45·2	47·5	**49·5**	48·5	48·7	48·0	48·0	47·0	41·5	39·2	49·5
Wadi Halfa	37·5	41·0	46·5	**52·5**	49·0	49·0	49·0	47·7	48·0	47·0	46·0	39·0	52·5
Jebel Aulia	39·0	43·5	43·4	45·0	**46·3**	46·0	43·1	41·3	43·4	42·0	40·2	39·9	46·3
Khartoum S.L.	39·6	42·5	44·5	46·3	47·3	**47·7**	47·0	43·0	45·3	44·7	41·5	40·2	47·7
Aroma	39·4	42·4	44·3	46·0	47·5	**47·8**	44·0	44·9	42·8	45·0	42·3	40·0	47·8
Gallabat	41·0	42·0	43·7	**44·0**	**44·0**	41·0	36·5	37·0	37·0	39·2	39·5	39·9	44·0
Gebeit	33·3	33·5	39·0	40·0	42·0	**43·0**	42·0	42·0	41·0	38·8	34·8	33·0	43·0
Kassala	41·6	44·0	45·3	45·8	46·0	**47·0**	41·5	39·5	43·0	43·5	43·0	41·2	47·0
Port Sudan	31·0	31·5	34·3	38·4	44·0	47·0	**47·5**	46·6	45·0	41·6	35·7	34·0	47·5
Tokar	35·5	37·5	42·5	44·5	47·0	**50·5**	49·5	47·5	46·0	44·0	40·0	37·2	50·5
Ed Dueim	40·4	43·0	45·0	**46·8**	46·5	44·5	42·5	40·5	43·0	43·5	42·0	40·5	46·8
Hag 'Abdullah	40·5	42·3	44·0	**46·1**	45·0	44·0	41·0	37·6	40·4	41·7	40·5	40·2	46·1
Rabak	39·0	42·3	43·4	**44·1**	43·0	41·3	39·0	35·0	38·4	40·7	39·1	39·7	44·1
Er Roseires	43·0	44·0	45·0	**46·0**	45·2	45·0	39·2	39·0	39·0	42·0	41·2	42·0	46·0
Sennar	41·3	43·2	45·4	46·0	**46·4**	44·5	41·8	39·0	40·5	43·0	41·0	41·0	46·4
Singa	42·5	43·0	45·0	**47·5**	45·5	44·2	40·0	38·5	41·0	42·0	41·0	41·0	47·5
Wad Medani G.R.F.	41·9	43·0	45·3	47·0	**48·0**	44·5	42·0	40·9	42·4	43·3	43·0	40·5	48·0
Wad Sha'ir	39·2	43·0	44·4	**46·1**	45·3	45·5	42·0	39·4	41·0	41·6	39·4	39·4	46·1
Wad et Turabi	39·0	43·0	43·5	**46·0**	45·5	**46·0**	42·5	40·0	44·5	43·0	41·5	39·0	46·0
En Nahud	39·0	39·7	42·0	**42·9**	42·3	40·0	39·0	35·2	38·1	39·8	37·8	39·2	42·9
El Obeid	39·7	41·0	43·0	44·2	45·3	43·0	40·2	**46·1**	39·9	41·0	39·3	39·5	46·1
El Fasher	38·5	41·0	43·5	**45·0**	**45·0**	44·0	43·0	44·4	41·0	41·0	39·5	38·0	45·0
Geneina	38·1	40·4	42·3	43·2	**45·2**	41·8	39·0	36·0	38·2	39·0	37·8	37·8	45·2
Akobo	41·5	42·2	42·0	**44·5**	40·0	38·5	37·1	36·5	36·2	37·6	39·4	41·5	44·5
Gambela	41·0	42·0	**44·0**	**44·0**	40·0	39·5	36·0	37·0	39·0	40·0	39·4	41·0	44·0
Malakal	40·9	42·4	**43·6**	**43·6**	42·1	41·5	36·6	36·5	38·0	40·0	39·8	40·5	43·6
Malek	41·4	41·8	**42·0**	40·7	39·0	36·0	36·8	35·2	35·7	37·6	39·1	39·8	42·0
Renk	39·4	42·2	43·4	**43·9**	43·2	40·2	39·4	35·1	39·4	41·2	39·3	39·8	43·9
Juba	42·2	43·0	42·0	42·4	**43·7**	37·2	36·7	36·5	37·9	39·6	40·4	40·8	43·7
Loka	**38·7**	37·6	38·4	37·0	35·0	33·5	31·9	31·9	33·5	36·0	35·5	37·3	38·7
Raga	42·0	42·6	**43·9**	42·2	41·0	37·4	35·7	36·4	36·8	38·7	38·9	39·9	43·9
Sources Yubo	37·0	**38·2**	38·0	35·7	35·0	32·5	31·0	32·0	32·5	33·7	35·5	36·5	38·2
Torit	43·0	42·1	41·4	**43·6**	39·8	37·3	35·4	35·6	38·3	39·9	39·8	39·7	43·6
Wau	41·0	44·0	43·0	**46·1**	42·1	41·0	40·0	40·0	39·0	40·0	40·0	40·0	46·1

The highest maxima occur in the north and the lowest in the south. The highest value ever recorded in the Sudan is 52·5° C. at Wadi Halfa in April 1903.

TABLE 4. *Mean Daily Minimum Temperature at certain Stations in the Anglo-Egyptian Sudan (in ° C.)*

Extremes are indicated in heavy type

Station	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Atbara	**14·0**	14·8	17·6	21·0	25·0	26·7	26·5	25·7	26·1	23·8	19·6	15·7	21·4
Karima	**11·9**	12·7	16·5	20·6	24·5	25·9	26·3	26·3	26·1	23·3	18·3	13·8	20·5
Wadi Halfa	**7·8**	8·7	12·4	16·9	21·1	23·1	23·2	23·8	22·4	19·7	14·3	9·3	16·9
Jebel Aulia	**15·5**	16·3	18·6	22·3	25·7	26·2	25·0	24·2	25·2	25·1	20·3	17·2	21·8
Khartoum S.L.	**15·2**	16·2	18·7	22·0	25·2	26·1	24·9	24·5	25·1	24·0	20·2	16·6	21·6
Aroma	**13·5**	14·2	16·5	19·9	22·8	22·9	22·0	21·6	22·0	21·3	17·7	15·2	19·1
Gallabat	16·0	17·9	20·0	21·7	21·8	19·8	18·5	18·3	18·4	17·9	16·3	**15·5**	18·5
Gebeit	15·4	**14·8**	15·5	17·2	19·4	21·8	23·7	23·5	21·8	18·8	18·4	17·1	19·0
Kassala	**15·9**	16·6	19·2	22·6	25·2	24·8	23·0	22·3	22·8	23·5	21·2	17·6	21·2
Port Sudan	19·9	**19·2**	19·7	21·5	23·8	25·7	28·1	28·8	26·5	24·8	23·7	21·5	23·6
Tokar	20·0	**19·7**	20·9	22·3	23·4	24·7	27·4	28·4	26·2	25·0	22·9	21·2	23·5
Ed Dueim	**14·4**	15·2	17·7	20·9	23·3	24·1	23·1	22·5	22·7	22·7	19·6	15·9	20·2
Hag 'Abdullah	**13·2**	14·1	16·7	20·6	23·4	24·0	22·4	21·7	21·7	21·4	17·4	14·5	19·3
Rabak	**16·0**	17·0	18·9	23·4	24·5	24·8	23·1	22·1	22·6	23·2	20·2	18·0	21·1
Er Roseires	**15·9**	17·2	19·8	22·4	23·3	22·1	21·2	20·8	20·6	20·1	18·1	16·3	19·8
Sennar	**15·1**	15·8	18·5	22·0	23·7	23·4	21·9	21·4	21·3	21·5	19·1	16·4	20·0
Singa	**16·3**	17·1	19·6	22·6	24·1	23·0	21·9	21·4	21·2	21·1	19·2	17·2	20·4
Wad Medani G.R.F.	**14·3**	15·0	17·8	20·9	23·8	24·3	22·6	22·1	22·0	21·9	18·4	15·3	19·9
Wad Sha'ir	**11·6**	12·8	14·9	19·2	23·2	24·0	23·0	22·0	22·0	21·1	15·9	13·4	18·6
Wad et Turabi	**12·7**	13·8	16·1	20·0	23·3	24·3	23·7	22·9	22·8	22·3	17·1	14·0	19·4
En Nahud	15·0	14·8	16·4	21·6	22·3	23·2	22·0	21·4	21·3	20·8	16·7	**14·6**	19·2
El Obeid	**11·6**	12·9	15·8	19·9	22·3	22·9	22·0	21·3	21·2	20·8	16·4	12·6	18·3
El Fasher	**9·8**	11·3	14·2	17·7	20·7	21·9	21·6	20·5	20·1	18·2	13·2	10·2	16·6
Geneina	**11·0**	13·2	15·2	18·9	20·0	20·8	20·6	19·6	18·7	16·1	13·9	12·2	16·7
Akobo	20·2	22·0	23·3	23·4	22·1	21·4	21·0	21·2	22·0	21·8	21·3	**20·0**	21·6
Gambela	**18·2**	19·7	21·3	22·0	21·4	20·7	20·4	20·3	20·1	19·6	18·9	18·3	20·1
Malakal	18·2	19·7	21·7	23·3	22·9	21·7	21·4	21·4	21·7	21·7	19·4	**18·1**	20·9
Malek	20·4	21·2	22·7	22·5	22·2	21·7	21·1	21·1	22·0	21·8	21·2	**20·0**	21·5
Renk	**15·2**	17·0	18·4	23·6	23·9	23·1	22·1	21·9	21·2	20·8	18·1	17·1	20·2
Juba	20·2	21·5	22·0	22·0	21·4	20·5	19·9	19·9	20·0	20·2	19·9	**19·8**	20·6
Loka	19·2	20·1	19·8	19·3	18·8	18·4	17·9	**17·8**	18·2	18·3	18·7	18·2	18·7
Raga	**12·8**	14·6	16·8	20·3	20·8	20·2	19·9	19·7	19·7	19·6	15·5	13·0	17·7
Sources Yubo	**18·5**	19·6	19·8	19·5	19·2	18·6	**18·5**	**18·5**	18·6	18·7	19·0	**18·5**	18·9
Torit	18·9	20·3	21·1	20·7	20·1	19·5	19·0	18·8	18·6	18·7	18·4	**18·2**	19·4
Wau	**17·6**	19·1	21·1	22·4	21·8	21·1	20·7	20·5	20·5	20·6	19·5	17·9	20·2

Throughout the Sudan the lowest mean minima occur in winter. Means for the year are lowest in the extreme north and in the west and highest in the Red Sea area. The seasonal variation decreases from north to south and is very small south of about the latitude of Malakal.

TABLE 5. *Lowest Minimum Temperature at certain Stations in the Anglo-Egyptian Sudan (in ° C.)*

Extremes are indicated in heavy type

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Atbara	**4·5**	6·4	8·0	11·0	14·5	18·0	17·3	19·8	19·0	17·0	9·5	8·0	4·5
Karima	3·8	**3·5**	7·5	12·5	15·0	18·8	20·8	20·5	20·5	15·5	8·5	6·3	3·5
Wadi Halfa	0·0	1·0	2·5	7·0	11·5	13·6	17·0	14·0	13·4	5·6	4·0	**−2·0**	−2·0
Jebel Aulia	**8·0**	**8·0**	9·2	14·9	17·5	19·3	17·6	16·5	18·5	16·8	12·1	9·1	8·0
Khartoum S.L.	**5·2**	6·9	9·3	11·4	16·3	19·6	19·0	18·0	16·0	16·5	12·5	7·0	5·2
Aroma	**5·2**	7·7	6·6	10·8	8·0	15·0	10·0	16·0	16·5	16·0	9·3	7·2	5·2
Gallabat	**9·0**	11·5	11·4	12·7	14·0	11·5	11·0	13·0	14·8	13·0	10·8	9·8	9·0
Gebeit	**7·5**	**7·5**	7·6	10·0	11·0	16·0	17·0	14·0	16·0	11·5	10·5	**7·5**	7·5
Kassala	**6·0**	7·5	9·2	11·5	15·0	16·0	15·0	15·0	15·0	16·5	10·4	7·1	6·0
Port Sudan	**10·0**	11·0	11·5	15·0	15·3	20·0	19·9	19·6	14·0	16·1	11·0	11·5	10·0
Tokar	**10·0**	12·0	13·5	14·5	15·0	14·9	20·5	19·2	19·0	19·5	16·0	13·0	10·0
Ed Dueim	**3·5**	5·0	7·1	9·5	10·6	14·0	15·5	18·0	13·0	14·5	8·5	5·6	3·5
Hag 'Abdullah	6·2	**5·6**	8·4	12·0	15·5	18·6	18·2	18·0	16·4	14·6	10·0	7·6	5·6
Rabak	10·4	**10·1**	11·6	18·5	20·1	20·3	19·4	19·7	19·2	19·0	14·5	11·5	10·1
Er Roseires	**7·5**	10·7	11·0	14·0	15·0	16·0	18·0	15·0	16·0	14·5	8·5	9·0	7·5
Sennar	**6·0**	8·1	9·5	13·4	16·0	18·4	18·0	18·5	17·0	14·0	12·4	8·0	6·0
Singa	**5·0**	9·5	10·5	13·0	13·0	13·0	16·0	18·0	14·0	15·0	11·5	9·0	5·0
Wad Medani G.R.F.	**5·6**	6·5	8·0	8·8	15·0	16·3	18·5	18·0	17·2	15·0	8·3	7·2	5·6
Wad Sha'ir	**5·0**	**5·0**	6·7	10·5	14·0	18·5	17·9	18·0	18·0	12·1	6·0	6·4	5·0
Wad et Turabi	**5·5**	6·5	6·5	9·5	14·5	15·0	19·0	19·0	15·0	12·5	9·2	6·5	5·5
En Nahud	8·0	**7·2**	8·5	15·0	18·0	18·5	18·5	18·0	18·0	17·0	10·5	10·0	7·2
El Obeid	**−0·4**	2·1	6·1	7·9	12·4	13·3	13·7	13·3	13·5	12·4	6·7	4·4	−0·4
El Fasher	**1·0**	**0·8**	4·5	10·0	11·5	14·5	16·3	14·5	13·0	10·5	5·0	2·0	0·8
Geneina	**6·4**	8·3	9·4	14·1	14·9	16·2	17·0	17·0	14·7	10·2	9·5	7·2	6·4
Akobo	15·6	16·2	17·1	19·5	18·5	17·8	18·5	18·5	18·5	18·3	15·7	**15·5**	15·5
Gambela	11·0	**9·0**	12·4	14·9	14·5	14·9	16·5	16·0	16·6	13·4	15·0	12·0	9·0
Malakal	**11·3**	11·4	13·0	15·0	16·0	17·1	16·5	16·3	18·0	17·1	12·5	12·2	11·3
Malek	15·6	**11·0**	17·0	18·5	19·0	19·3	18·4	18·5	18·1	19·1	18·2	11·5	11·0
Renk	**10·0**	12·0	10·1	19·1	19·5	18·9	19·6	18·5	18·3	17·4	11·5	10·9	10·0
Juba	15·5	15·6	16·3	17·8	17·0	16·0	16·7	16·0	16·0	14·0	**13·2**	15·0	13·2
Loka	12·7	16·0	10·0	14·0	10·6	15·0	13·2	11·4	15·5	15·4	13·4	**9·1**	9·1
Raga	5·9	7·2	8·5	11·2	15·0	17·0	13·9	16·4	12·6	15·8	10·0	**5·5**	5·5
Sources Yubo	**12·0**	15·0	16·0	14·0	14·0	15·5	13·0	15·4	15·5	16·0	15·0	14·0	12·0
Torit	**13·1**	**13·1**	15·1	16·0	13·4	16·0	15·0	13·8	14·5	13·2	13·5	13·2	13·1
Wau	**10·0**	10·5	12·0	14·0	14·0	14·0	14·5	15·0	15·0	16·0	12·0	**10·0**	10·0

The lowest minima occur inland in the north and the highest in the Red Sea area and the south. The lowest value ever recorded in the Sudan is −2·0° C. at Wadi Halfa in December 1917.

TABLE 8. *Mean Relative Humidity at 0800 Hours at certain Stations in the Anglo-Egyptian Sudan (per cent.)*

Station	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Atbara	39	31	25	20	18	18	28	38	29	26	34	41	29
Karima	35	28	22	17	16	16	28	38	28	27	32	36	27
Wadi Halfa	51	43	33	25	23	22	25	31	34	37	45	50	35
Jebel Aulia	49	40	35	32	35	46	63	72	62	46	46	52	48
Khartoum S.L.	36	26	21	18	25	38	57	68	54	37	33	38	38
Aroma	70	66	61	48	43	52	64	70	65	54	58	67	60
Gallabat	45	43	36	38	53	68	78	80	77	67	54	49	57
Gebeit	..	..	..	..	..	..	..	..	..	..	..	..	..
Kassala	62	56	48	40	40	49	66	72	65	48	52	60	55
Port Sudan	66	65	64	56	45	37	39	41	47	66	68	69	55
Tokar	73	70	68	65	54	40	40	47	48	61	66	72	59
Ed Dueim	33	27	21	20	33	48	65	74	67	49	37	36	42
Hag 'Abdullah	36	26	20	20	34	52	69	78	72	53	35	38	44
Rabak	27	27	24	27	39	55	72	80	74	56	30	30	45
Er Roseires	41	34	27	31	48	66	79	83	80	70	49	42	54
Sennar	46	41	33	34	45	60	76	81	75	58	46	48	54
Singa	42	39	31	34	45	61	75	81	76	62	44	44	53
Wad Medani G.R.F.	36	26	21	20	31	48	67	77	70	50	36	39	43
Wad Sha'ir	41	35	25	24	33	51	67	77	69	51	37	42	46
Wad et Turabi	36	27	21	20	27	41	62	71	64	45	36	38	41
En Nahud	37	30	26	30	47	63	72	79	72	51	29	32	47
El Obeid	37	28	23	26	41	56	73	79	69	48	33	36	46
El Fasher	35	28	24	21	31	47	65	74	61	37	31	34	41
Geneina	31	29	38	37	40	57	81	90	82	49	34	33	50
Akobo	43	43	45	63	75	79	84	85	84	78	71	58	67
Gambela	55	50	49	61	74	79	83	85	78	72	66	59	68
Malakal	27	23	27	48	65	76	84	85	82	77	50	32	56
Malek	46	49	61	71	80	83	87	87	83	79	68	56	71
Renk	40	34	23	38	54	65	79	77	75	66	41	39	53
Juba	54	56	65	75	82	83	87	88	83	80	75	64	74
Loka	48	58	66	76	81	83	86	86	82	80	72	59	73
Raga	56	51	56	71	80	86	89	89	89	86	72	60	74
Sources Yubo	57	65	71	82	86	87	88	89	86	85	76	66	78
Torit	39	45	53	67	73	75	79	79	74	72	62	53	64
Wau	46	42	48	65	73	78	83	85	82	79	70	56	67

The relative humidity is expressed as percentage saturation. Sudan standard time, 2 hours fast on Greenwich mean time, is used.

TABLE 9. *Mean Relative Humidity at 1400 Hours at certain Stations in the Anglo-Egyptian Sudan (per cent.)*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Atbara	17	12	11	10	10	10	14	18	15	13	17	18	14
Karima	19	14	11	9	9	9	14	18	14	13	18	21	14
Wadi Halfa	26	19	12	10	11	10	13	16	17	18	24	26	17
Jebel Aulia	30	23	20	18	20	22	35	46	36	26	28	33	28
Khartoum S.L.	20	14	11	10	13	19	32	41	30	20	19	22	21
Aroma	..	..	..	..	..	..	..	..	..	..	..	..	..
Gallabat	18	20	22	26	36	45	61	65	61	45	30	27	38
Gebeit	..	..	..	..	..	..	..	..	..	..	..	..	..
Kassala	29	25	24	23	26	29	43	48	40	29	30	31	31
Port Sudan	65	66	63	59	51	45	44	47	51	64	64	66	57
Tokar	..	..	..	..	..	..	..	..	..	..	..	..	..
Ed Dueim	..	..	..	..	..	..	..	..	..	..	..	..	..
Hag 'Abdullah	..	..	..	..	..	..	..	..	..	..	..	..	..
Rabak	15	15	16	17	23	30	41	53	41	24	16	18	26
Er Roseires	..	..	..	..	..	..	..	..	..	..	..	..	..
Sennar	..	..	..	..	..	..	..	..	..	..	..	..	..
Singa	..	..	..	..	..	..	..	..	..	..	..	..	..
Wad Medani G.R.F.	16	12	8	9	14	22	37	48	39	23	16	17	22
Wad Sha'ir	..	..	..	..	..	..	..	..	..	..	..	..	..
Wad et Turabi	..	..	..	..	..	..	..	..	..	..	..	..	..
En Nahud	18	19	16	22	30	37	48	48	40	24	18	17	28
El Obeid	24	20	16	16	22	30	45	52	40	25	21	21	28
El Fasher	13	11	11	11	14	18	33	42	28	15	13	12	18
Geneina	11	13	19	17	18	24	46	60	43	20	14	11	25
Akobo	27	25	26	38	50	52	61	63	57	52	42	34	44
Gambela	..	..	..	..	..	..	..	..	..	..	..	..	..
Malakal	17	16	15	25	41	52	60	63	58	50	28	20	37
Malek	29	30	35	43	55	58	63	64	61	54	43	36	48
Renk	24	23	15	23	33	41	54	54	49	34	24	24	33
Juba	26	28	34	44	54	56	60	59	53	48	40	33	45
Loka	25	32	41	52	59	62	66	65	60	55	43	32	49
Raga	26	26	28	38	48	58	64	66	61	52	32	26	44
Sources Yubo	..	..	..	..	..	..	..	..	..	..	..	..	..
Torit	..	..	..	..	..	..	..	..	..	..	..	..	..
Wau	21	20	22	34	44	50	56	56	52	46	30	23	38

The relative humidity is expressed as percentage saturation. Sudan standard time, 2 hours fast on Greenwich mean time, is used.

TABLE 10. *Mean Rainfall at certain Stations in the Anglo-Egyptian Sudan (in millimetres)*

Station	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*	*Var.* %
Atbara	..	..	..	1	3	2	18	38	6	2	..	..	70	46
Karima	..	..	..	..	1	..	8	14	2	..	..	..	25	38
Wadi Halfa	..	..	tr	0·1	tr	..	..	tr	..	tr	..	..	0·1	40
Jebel Aulia	..	..	..	1	3	20	56	89	29	7	..	..	205	30
Khartoum S.L.	..	..	..	1	4	9	52	75	18	4	..	..	163	34
Aroma	..	..	..	3	4	20	50	80	26	3	1	..	187	25
Gallabat	..	..	4	15	67	164	203	252	159	40	3	..	907	10
Gebeit	1	..	2	4	9	9	22	49	13	8	2	1	120	44
Kassala	..	..	1	3	12	30	91	124	58	8	..	..	327	21
Port Sudan	7	3	2	1	1	..	5	3	..	13	44	27	106	56
Tokar	21	4	1	2	3	2	4	2	..	10	17	19	85	37
Ed Dueim	..	..	1	2	14	26	97	125	50	13	..	..	328	18
Hag 'Abdullah	..	..	..	5	22	44	133	162	69	13	1	..	449	15
Rabak	..	..	..	3	18	51	108	145	54	20	..	..	399	18
Er Roseires	..	1	2	16	62	128	186	222	155	31	5	..	808	13
Sennar	..	..	..	3	24	60	119	160	70	17	1	..	454	16
Singa	..	..	..	5	33	72	160	187	88	27	2	..	574	13
Wad Medani G.R.F.	..	..	..	4	11	36	135	143	59	12	1	..	401	22
Wad Sha'ir	..	..	..	1	10	35	79	102	41	5	..	..	273	19
Wad et Turabi	..	..	..	2	11	35	73	87	36	6	1	..	251	25
En Nahud	..	..	..	5	27	43	100	123	86	18	1	..	403	19
El Obeid	..	..	1	2	17	38	98	121	75	16	..	..	368	20
El Fasher	..	..	..	1	10	17	109	134	34	5	..	..	310	30
Geneina	..	..	..	6	24	47	167	228	69	5	..	..	546	17
Akobo	1	2	19	83	134	117	142	177	130	65	18	3	891	10
Gambela	6	11	34	82	160	174	224	243	180	95	48	13	1,270	13
Malakal	..	..	6	31	80	130	174	184	136	74	10	1	826	18
Malek	6	7	34	84	121	115	123	131	120	87	18	9	855	18
Renk	..	..	..	8	34	79	124	134	87	42	5	..	513	16
Juba	4	15	32	121	150	134	121	133	106	94	35	17	962	14
Loka	14	26	60	151	166	162	174	194	131	159	64	25	1,326	12
Raga	..	3	16	58	148	120	227	258	200	93	12	2	1,137	10
Sources Yubo	5	24	64	102	189	220	169	214	234	171	52	15	1,459	10
Torit	4	25	45	106	129	117	143	147	95	96	47	17	971	9
Wau	1	6	24	65	135	166	191	209	167	124	14	1	1,103	12

The mean rainfall and the length of the rainy season increase from north to south except in the Red Sea area. The mean variability decreases from north to south. The convention used to express the variability is described in the explanatory notes for Fig. 28.

TABLE 11. *Mean Daily Piche Evaporation at certain Stations in the Anglo-Egyptian Sudan (in millimetres)*

Station	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Atbara	13·7	16·1	18·9	20·8	20·9	20·5	18·1	15·9	16·3	16·2	14·6	13·4	17·1
Karima	11·7	13·9	17·0	19·7	21·2	21·1	18·9	16·9	19·2	17·8	14·2	11·9	17·0
Wadi Halfa	8·8	10·8	14·7	18·1	20·1	21·4	19·3	17·7	18·3	16·0	11·6	8·9	15·5
Jebel Aulia	14·1	16·6	19·6	22·0	20·8	19·3	13·5	9·9	12·4	15·8	15·2	13·8	16·1
Khartoum S.L.	12·0	14·5	17·0	18·4	17·7	16·3	12·7	9·9	11·4	13·6	13·2	11·7	14·0
Aroma	11·1	12·9	15·3	18·0	18·6	17·2	13·5	10·4	11·7	14·4	13·3	11·6	14·0
Gallabat	13·1	15·4	17·9	18·1	14·0	8·7	4·4	3·2	3·6	5·9	9·5	11·6	10·5
Gebeit	4·6	5·4	7·5	10·4	12·7	13·9	13·7	11·1	11·5	8·8	5·6	4·8	9·2
Kassala	9·7	10·9	13·6	15·7	15·0	12·7	8·8	6·5	7·7	11·4	11·4	9·7	11·1
Port Sudan	7·4	7·7	8·1	9·2	11·0	14·1	14·5	13·6	10·8	7·1	7·2	7·2	9·8
Tokar	7·6	7·4	8·4	10·2	12·9	19·3	22·0	22·5	17·0	12·5	11·4	9·1	13·4
Ed Dueim	14·5	16·3	18·3	18·7	16·2	13·5	9·4	6·3	7·5	11·2	15·1	14·3	13·4
Hag 'Abdullah	13·9	16·6	19·4	20·6	17·7	15·0	9·4	5·6	6·2	9·4	13·2	12·9	13·3
Rabak	17·3	20·6	24·1	25·4	20·8	18·0	11·0	7·8	8·6	13·3	19·1	19·7	17·1
Er Roseires	13·2	15·0	16·6	16·2	12·9	8·5	5·2	4·2	4·6	6·8	10·9	12·5	10·5
Sennar	15·4	17·7	20·3	20·2	17·0	14·2	8·5	5·6	6·5	10·5	15·1	15·0	13·8
Singa	14·5	16·3	18·0	18·0	14·3	10·8	6·4	4·2	4·9	8·0	13·2	14·5	11·9
Wad Medani G.R.F.	15·4	18·1	21·3	23·1	20·4	18·3	11·4	7·2	8·2	11·9	15·0	14·6	15·4
Wad Sha'ir	15·0	18·3	21·9	23·9	21·0	18·5	12·4	7·8	8·9	12·0	14·3	14·3	15·7
Wad et Turabi	15·3	18·0	21·0	24·0	22·5	20·1	13·4	9·5	10·8	13·8	14·5	13·8	16·4
En Nahud	16·0	18·0	19·8	19·0	14·7	11·5	7·2	5·4	6·8	11·7	15·4	15·4	13·4
El Obeid	13·4	15·1	16·9	17·8	15·7	13·2	8·7	6·0	7·1	11·9	13·9	13·1	12·7
El Fasher	9·8	11·6	13·6	15·1	14·5	12·8	8·5	5·9	8·5	11·7	10·9	9·6	11·0
Geneina	..	..	..	..	..	..	..	..	..	..	..	..	..
Akobo	12·1	13·8	13·2	9·2	6·3	4·7	3·6	3·3	3·3	4·4	5·9	8·6	7·4
Gambela	8·4	9·8	10·4	8·0	4·6	3·6	2·7	2·6	3·2	4·1	5·2	6·6	5·8
Malakal	16·5	18·2	16·3	11·1	7·2	4·5	3·0	2·5	2·9	3·8	8·6	13·9	9·0
Malek	10·6	10·1	9·1	6·7	4·4	3·2	2·6	2·5	3·1	4·3	7·1	8·5	6·0
Renk	16·2	19·0	21·8	18·6	15·1	12·6	7·4	4·4	4·9	8·4	15·0	16·0	13·3
Juba	11·7	11·5	9·5	7·1	4·6	4·2	3·1	3·3	4·2	5·3	6·7	9·2	6·7
Loka	10·8	9·4	7·6	4·7	3·4	3·2	2·5	2·6	3·2	3·7	5·5	7·9	5·4
Raga	8·2	8·4	8·8	6·4	4·3	3·0	2·3	2·0	2·3	3·1	5·6	7·5	5·2
Sources Yubo	..	..	..	..	..	..	..	..	..	..	..	..	..
Torit	12·7	11·9	10·6	6·9	4·8	4·6	3·5	3·5	4·7	5·6	7·3	10·0	7·2
Wau	11·9	12·5	12·2	9·2	6·4	4·7	3·7	3·4	3·9	4·7	7·8	10·4	7·6

The values given are higher than those which would be obtained for the evaporation from an open freshwater surface. To obtain approximate values for the latter they should be multiplied by an experimentally determined reduction factor of 0·5. The evaporation decreases from north to south.

CHAPTER VI

GEOLOGY OF THE SUDAN

By G. ANDREW, *Government Geologist*

'Such stuff the world is made of.' COWPER, *Hope*, l. 211.

I. INTRODUCTION

IN the account of the main geological features of the Anglo-Egyptian Sudan which follows, special emphasis is laid on the development of the surface. In order to do this within a reasonable compass it has been necessary to omit details in presenting a comprehensible picture of the march of events. Imagination has been ridden with a slightly looser rein than is permissible in countries where accumulated fact is denser in proportion to area.[1] Geological time-divisions and their names are sparingly used; a reference-scale is given for these at the end of the glossary. Co-ordinates of place-names used in the text are listed but the major features are omitted from this list, e.g. el Obeid, Nuba Mountains, Sobat River, &c.

Details of the sources of information are not given in the text. A bibliography of the Sudan up to 1937 was published by R. L. Hill in 1939 and a later bibliography appeared as Bulletin No. 3 of the Geological Survey (Khartoum) in 1945.

History of Research

The earliest account of the geology of the Sudan was by Russeger, who made extensive excursions in search of mineral wealth early in the nineteenth century. Schweinfurth also travelled through the Sudan, but appears to have collected less geological information than he did in Egypt.

The Geological Survey began in 1905 by the appointment of T. Barron. After his early death in 1906 the survey was carried on by G. W. Grabham (1907–39), G. V. Colchester (1922–32), and J. M. Edmonds (1934–9); G. Y. Karkanis joined the staff in 1918.

During the period numerous reports were written on a wide range of subjects: pottery, brick, and tile materials; limestone; building sites; soils; water-supply. The geological side of the work of the Egyptian Irrigation Department and for the Sennar and J. Auliya dams was done by the Geological Survey. Publications issued included bulletins on water-supply and mineral resources, a handbook for non-geologists on how to collect specimens and information, and a number of contributions to the publications sponsored by the International Geological Congress (on coal, iron ore, gold).

Interpretation of facts has depended very largely on published contributions from contiguous countries. In the case of the Pleistocene, how-

[1] The area of the Anglo-Egyptian Sudan is 967,500 sq. miles (2,505,800 sq. km.), or four and a half times that of continental France, about a third of that of Australia, or a quarter of that of Canada.

ever, the succession of sediments, the time-scale shown by artefacts, and the variation of climate have still to be worked out on internal evidence. The Sudan is intermediate between Kenya–Uganda and Egypt and will no doubt eventually provide important evidence on Pleistocene events.

For a long time the maps published by Russeger in the middle of the nineteenth century were the only source of general geological information. Seven geologists from abroad have visited the country south of Halfa and have published geological accounts in the twentieth century; Johannes Walther, W. H. Hobbs, K. S. Sandford, and E. J. Wayland, and three prospectors, A. Llewellyn, G. Linck, and W. H. Tyler, published geological reports of the areas visited.

The Geological Survey of Egypt carried out work in the Sudan; W. F. Hume made a traverse up the Nile from Halfa to Uganda, T. Barron visited Chelga in Abyssinia, and J. Ball studied the Nile as far as Semna.

A certain amount of geological work has been done by commercial concerns formed to prospect and exploit mineral resources. The geological side of this work was summarized by Dunn (1911) and by publications in scientific journals (Linck, 1901–3; Wilcockson and Tyler 1933); Llewellyn's investigation of the north-east Sudan were also published (1903).

A large number of accounts by travellers contain some geological information, and for the remoter parts of the Sudan this is often the only information available.

The most important recent work on the region has been carried out by K. S. Sandford and W. J. Arkell on the Nile valley as far as Semna, and by K. S. Sandford in the north-western desert area.

H. Lynes and W. C. Smith described a part of Kordofan and Darfur; *The Times* African Flight discovered an unknown volcanic field in the Bayuda desert (Gregory, 1920; Grabham, 1920), and Edmonds has described the Kordofan sands.

The importance of the Nile to Egypt is reflected in the large volume of publication. Sir H. G. Lyons's contributions include the first complete and detailed account of the river (1906) and were followed by many publications of the Egyptian Physical Department (H. E. Hurst and P. Phillips).

G. W. Grabham and R. P. Black studied the Lake Tana region in 1920–21.

A considerable amount of information is available, collected by the Geological Survey and sent in by prospectors, travellers, and Government officials; the geological account which follows collects this information together in the form of a general summary.

A short glossary of geological terminology is given on pp. 124–6.

Topography

The territory included within the political boundaries of the Anglo-Egyptian Sudan occupies a major part of the Nile basin. A small sector in western Darfur lies west of the Nile–Chad watershed between north latitudes 10° and 15°, and part of the Red Sea Hills region drains towards the east.

The country is a vast plain of deposition, for two reasons; the general slope of the ground is very gentle and the rainfall is insufficient to produce persistent run-off which escapes from the area via the Nile.

To the south and east the main watersheds lie outside the country. The Blue Nile rises on the Abyssinian plateau, and the Sudan frontier extends only as far as the foot-hills of this upland region (Roseires 464 m. R.L.[1]). The White Nile originates on the Uganda plateau, and enters the Sudan, through Lake Albert rift valley, at Nimule (615 m.). The Sobat rises on the Abyssinian plateau and has fallen to a level of 450 m. at Gambeila.

The Nile–Congo divide is low in the south (Sources Yubo 715 m.), although isolated hills are over 1,000 m. in height and the Aloma plateau south of Yei rises to over 800 m. The head of the river Umbelasha is somewhat higher (Tinga Peak, 1,313 m.). The Nile–Chad divide north of the river Umbelasha is of low-rolling dune country at a little above 600 m., but the watershed rises steadily north to Jebel Marra crater (3,087 m.) and maintains a high level west of Kutum north to Jebel Matariq (1,681 m.). Along the north-west frontier the Erdi plateau stands at 1,300–1,450 m.; the plateau at the head of Wadi Howar is a little lower (1,270 m.) and Jebel 'Uweinat rises to 1,895 m.

Within the country there are low watersheds separating the northerly slopes of the north-west desert area from the southerly slopes of the southern Darfur[2] and south-west Kordofan, and between the Blue Nile and White Nile basins. The first runs south-east from Jebel Matariq north of Kutum to the Meidob Hills and thence in an easterly direction towards the White Nile near Dueim (*c.* 14° 30′ N.). The country south of this watershed is divided by the Nuba Mountains into a western part sloping towards the Bahr el 'Arab and a narrow eastern part sloping towards the White Nile, and this meridional watershed along the western side of the Nuba Mountains meets the east–west watershed near El Obeid.

The watershed between the Blue and White Niles now extends from Khartoum via Manāqil to near Kurmuk. The north part of this is formed by a relatively recent superficial deposit, and the rock-watershed, now breached by the White Nile, probably continued from the Kutum–Dueim line to Manāqil.

The lower ground of the Sudan is a plain of desert erosion in the north, and a plain of accumulation or aggradation in the south. The line between these two areas follows the Kutum–Dueim watershed, and then appears to pass north of the Butana to the Atbara near Khashm el Girba. The Gash Delta is also an aggradation area in the arid region.

The hilly regions of the Sudan take their character from the underlying rocks.

Volcanic masses are sculptured by running water where they form high country (J. Marra) and there is a tendency to develop naturally terraced

[1] Heights are given in metres above mean sea-level at Alexandria. The zero of Khartoum gauge (P.W.D.) on the Blue Nile is the datum for the Sudan, at 360·00 m. R.L. All reduced levels are given without indication of accuracy.

[2] In this chapter Darfur, Kordofan, and Equatoria mean the Provinces bearing these names.—*Editor.*

hills and plateau structure (Boma), diversified by steep-sided sugar-loaf hills where erosion has removed the sides of a vent and left only the tougher central plug. Craters still retain their form in many parts (Marra range, Meidob, Bayuda desert).

The Nubian sandstone forms dissected plateau-country with flat-topped outliers (mesa, butte) as an advanced stage of stream-erosion. The amount of dissection varies with the intensity of rainfall and the escape-level of streams. The Libyan desert is of low relief as a rule; deeper dissection can be seen in the hills near Umm Keddada (hill-tops to 770 m., plain-level, 583 m.) and in the country west of the Wadi Muqaddam to Wadi el Melik.

The basement complex forms rugged hills where the escape-level of erosion allows deep incision by streams. This is the case in the Red Sea Hills (Erba, 2,217 m.). On the western slopes of these hills a more subdued topography grades into the plain, with inselberg, partly drowned in sediment.

In the northern part of the Sudan insolation and transport by wind are the most active agents of denudation in the Nile basin. In the Red Sea Hills the action of running water is the principal erosive agent, although arid weathering sculptures protruding rock-masses into characteristic forms.

In the southern Sudan rainfall is greater, smoother outlines are more common and, except where soil-erosion has been accelerated to completion by destruction of vegetation, hills are protected from the effects of insolation. They have the inselberg character even in the extreme south, with steep plunging sides, which is commonly regarded as characteristic of a mature phase of denudation under arid and semi-arid conditions.

The nature of the rock has a considerable influence in determining hills and low ground. In the region where insolation is the principal agent of comminution, the hardest rock does not invariably stand out as a hill-former. The action of diurnal temperature-range shatters coarse heterogeneous rocks to a sand, but produces only a coarse scree-type of debris from a fairly homogeneous, fine-grained, thermally isotropic rock.

The surface of such rocks becomes cloaked with debris too coarse for removal by wind or rainwash; unless attacked by a flowing stream, this cover of debris is stable. The granitic type of rocks, especially if foliated, and other coarsely crystalline rocks are reduced to a coarse sand. It is a common feature of the eastern desert of Egypt and the north-west Sudan to find coarse granite so friable that foxes have dug holes in it, although minerals normally susceptible are still undecomposed. This type of rock forms low ground. In granite country fine-grained rocks within the granite protrude as wall-like masses, and the paraschists surrounding the granite often form a ring of hills around the low granite outcrop.

The soda-granites and some of the fine-grained unfoliated granites are an exception to this empirical rule; they do not attain greater heights than the surrounding rocks in the desert region, but reach comparable heights. This is due to the massive jointing.

In the south the granoblastic and foliated rocks of Equatoria behave more normally under present-day erosion, e.g. Imatongs, Garia, Kinyeti.

The effect of salt-concentrations at the surface is an important agent of rock-weathering. On ill-drained ground salts are responsible for destruction of susceptible minerals, of felspathic and ferromagnesian rocks (granites, basalt, mica-schist), but are relatively impotent against sediments such as non-felspathic sandstone, argillaceous deposits, rhyolites, ironstone. Salts actually increase coherence of sediments consisting of weathered material. A thin hard salt-cemented crust is formed along the coastal plain of the Red Sea, and iron-oxide has the same effect on some sand-dune surfaces. On better-drained slopes salt-concentration only takes place along stream-beds. Weathering by the action of salts is therefore not particularly noteworthy in the hills.

A good example of the characteristic inselberg scenery of the Sudan is seen near the Sabaloka hills, and the same area provides an example of insolation denudation. The river has dug a gorge through a flat-topped hill-mass of rhyolites originally covered by the Nubian Series and is in a superposed drainage-line (antecedent drainage).

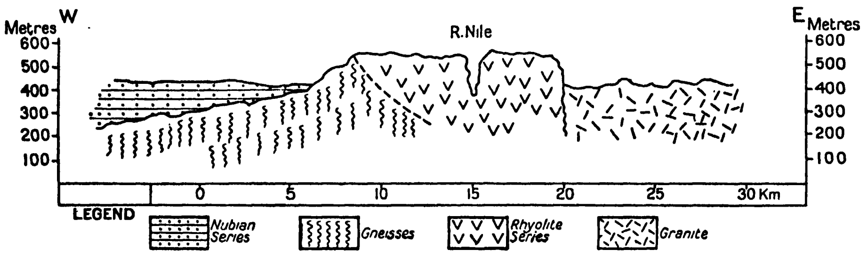


FIG. 30. Diagrammatic section of the Sabaloka gorge.

This hill-mass is a part of the pre-Nubian landscape, now standing out as a result of the removal of the sandstone cover. A remnant of this cover still remains on the top of Jebel Rauwiyan at the south-west end of the gorge and on another hill to the south. The level of the base of the Series is near the top of the rhyolite plateau.

To the east the gneiss outcrops as low ground, probably reduced to near its present level by pre-Nubian erosion. To the south and west a coarse granite outcrops. This builds sugar-loaf hills which reach a level below that of the Sabaloka summit plateau, rising from a low plain of the same granite as exfoliating inselbergs.

This area illustrates the power of the river erosion to maintain a channel through the highly jointed rhyolites which are more resistant against the insolation-weathering outside the river-bed than is the coarse granite or the coarse gneiss of the area.

The north-western Sudan plain is mainly a denudation plain. The flatness of the plain is due to erosion under arid conditions and to the nature of the underlying rock. The country is of nearly horizontal sandstones and mudstones of the Nubian Series, with a few inliers of the pre-Nubian surface of the basement complex.

Denudation proceeds under arid conditions by insolation and wind-transport. The rock is comminuted and the finer material blown away, to be accumulated as dunes or in hollows and in the end to reach the Nile.

The coarser material accumulates on the surface as a protective layer and slows down the lowering of the surface.

Sand-blast attacks the base of prominences and scarps, and its sculpturing effect is very obvious.

In general denudation in the desert is very slow, owing to the absence of running water; this is shown by the steep-sided plateau formed of soft rocks flanking the Nile from Halfa to Assiut. The tendency is to produce a monotonous and practically stable hamada plain.

The central and southern plain is different in character, though its persistence is in part due to feeble stream-erosion. The plain is composed of relatively recent sediments, locally of great thickness (over 278 m. under Umm Ruwaba), and is stable because of the escape-level of the Nile at the upper end of the Sabaloka gorge (deepest point, 359·5 m. R.L.). This is more fully discussed in the section dealing with the superficial deposits of the Nile valley (p. 106).

West of the White Nile and south of the margin of the north-western desert the low ground is occupied by a vast spread of dune sand, now stable (Kordofan sands or 'qōz'; Edmonds 1942), which forms a rolling plain on which drainage-lines are suppressed owing to the absorption of rainfall.

The drainage of the region is mainly towards the Nile, but from most parts fails to reach the Nile as a surface-flow; there is no evidence of underground flow.

The rivers of western Equatoria (Bahr el Ghazal, Bahr el 'Arab) drop nearly all their suspended sediment in the swamps and lose much of their volume there. The Bahr el Jebel enters the Sudan at Nimule with a minimum of mechanical sediment and what is picked up between Nimule and Juba is removed in the 'sudd' swamps. The Sobat similarly loses both volume and sediment before joining the White Nile.

The south-flowing streams of Kordofan and Darfur either fail to reach the river or make no appreciable contribution to either its flow or sediment. Only local rainwash is added to the White Nile between Malakal and Khartoum. This stream carries only very fine muds and organic matter, even in flood.

The Blue Nile is the main carrier of mechanical sediment, flowing on a bed of alluvial sands throughout its course. It receives a noteworthy contribution of water from the Rahad and Dinder, but little from the Sudan plain.

Below Khartoum local khors run for a few days after rain, but only the Atbara contributes materially both sediment and water to the Nile. Drainage from the Wadi Melik rarely reaches the Nile; the Wadi Muqaddam is not distinguishable as a watercourse near the river. Some drainage escapes from the Bayuda (Wadi ed Dom to Merowe, Wadi Abu Haraz to Berber), but only rare local rainwash reaches the Nile on the right bank. The Atbara is without active affluents north of Khashm el Girba; the Gash (Kassala) and Wadi 'Arab (Musmar) fail to reach the river.

In the Red Sea Hills the Baraka flood occasionally reaches the sea and other small streams (Khor Arba'at, Kh. Mog near Port Sudan, and khors near Suakin) reach the coastal plain and may exceptionally reach the sea, but floods are generally absorbed by the sediments of the plain.

Geological Summary

The geological formations which build the Sudan are given in the table on p. 91.

The platform, on which the Nubian Series of quasi-horizontal sandstones and mudstones was deposited, is of folded, more or less altered (metamorphosed or recrystallized) sediments and bedded volcanic rocks. These were altered, folded, and intruded by igneous rocks, elevated to form a land-surface, and denuded to form the sub-Nubian peneplain.

The later history of the region lacks any folding movement of the type which produces mountain-ranges. The region was inundated by the sea during the deposition of parts of the Nubian Series, though the inundation appears to have been of an oscillatory character and the sea was never deep.

The sea-margin retreated steadily through the Eocene period, and although a return of marine invasion occurred along the coasts of Egypt and Somaliland, the Sudan has been under sub-aerial erosion for a long period of time, probably since the Cretaceous. As a result of this there have been extensive tracts swept clean of the Nubian Series. There are few traces of post-Cretaceous events, since deposition is normally only a temporary feature of land-surfaces and any surface-accumulations tend both to be thin and to be removed by denudation soon after their deposition.

There are important Tertiary deposits. The Hudi Chert is preserved partly because of the protection afforded by later sheets of volcanic rock and partly as it is resistant to weathering. One of the lateritic ironstone sheets is regarded as mid-Tertiary; it caps a peneplain not far above the present erosion-level in the western part of Equatoria. The volcanic rocks are sub-aerial deposits of late Tertiary accumulation and owe their preservation to their bulk, toughness, and youth.

The movements which have affected the Sudan since the deposition of the Nubian Series consisted of gentle warping with uplift of the eastern part of the region, accompanied by faulting in the east. In the east the Red Sea Hills and Abyssinian plateau rose and the Red Sea was formed. The plateau has tended to continue this rise slightly (against mean sea-level), shown by marine sediments now above water on the present coastal plain. Its height was further increased by extensive volcanicity which produced a thick mantle of lava, now capped by (extinct) volcanoes of the Jebel Marra type.

This elevation of the eastern margin of the Sudan was produced by a warping movement, resulting in a hollow running north and south; this now forms the central plain of Egypt and the Sudan along which the Nile flows. The oscillation of the sea in Cretaceous and Eocene times shows that there was a general inclination northwards in Egypt and the northern Sudan throughout this period, which has since been maintained by erosion. Depressions have formed in the plain, now filled by unconsolidated sediments.

Within the plain the identification of structures such as folds and faults is far from easy. In the first place the region is capped by thick super-

Table of Succession

Era	Period	Succession		
QUATERNARY	Recent	(15) Nile Valley alluvium		
		(14) Kordofan 'qōz' ‖	clays of plain ‖	Red Sea terraces and raised reefs
	Pleistocene	(13) Palaeolithic gravels bordering Nile		Red Sea marine deposits
TERTIARY	Pliocene	(12) Umm Ruwaba Series ‖	(11) Volcanicity	
	Miocene	Rise of Red Sea hills and Abyssinian plateau		
	Oligocene	(10) Ironstone phase on plateau*		
	Eocene	(9) Hudi Series (chert) Beginning of rise of eastern plateau (? upper Eocene) erosion gap		
MESOZOIC	Cretaceous	(8) Nubian Series of north-western Sudan		‖ Yirol beds
	Jurassic	(8) Nubian Series of eastern Sudan		
	Triassic	Erosion gap; no major movement		
PALAEOZOIC	Upper Palaeozoic	(7) Continental sandstone of Ouadai–Darfur frontier ‖	Nawa Series	
		Establishment of peneplain under quasi-horizontal continental sediments, of Nubian Series' type		
	Lower Palaeozoic	(6) Soda-granites (5) Unfoliated granites		
PRE-CAMBRIAN		(1–4) Last folding of basement complex basement complex see p. 92.		

‖ No correlation implied.
* The oldest ironstone is attributed to the middle Tertiary; later ferruginous deposits are neither specifically distinguished nor dated.

ficial deposits, and outcrops are widely scattered. Secondly the Nubian Series is monotonous in lithology, lacking easily identifiable strata and significant fossils. Only by detailed study, hitherto not attempted, can recognizable horizons be traced laterally and structures such as faults identified. It seems probable that post-Nubian faulting in the plain is not common and that vertical movements were not large. A further complication is the irregularity of the base of the series, so that differences in level of the basal surface in a few kilometres cannot be interpreted as due to faulting without some definite evidence.

The present operation of denudation acts so as to obscure structural differences. In a region undergoing denudation mainly by running water (stream erosion) fault-lines are often marked out by the behaviour of rivers or by scarps, and the trend of rocks is shown by features on the surface.

In the Sudan such features appear only in hilly regions. The course of a stream is influenced (diverted) more by the alluvium of the plain (particularly by the alluvium deposited by tributaries) than by hard and soft rock-formations.

The Tertiary and Quaternary history of the Sudan is represented by non-marine deposits and by peneplains, and by volcanic accumulations, as is generally the case in Africa.

II. The Geological Succession

1–6: *Basement complex*[1]

This includes all igneous and sedimentary rocks, whether metamorphic or not, out of which the platform was carved on which the quasi-horizontal continental sediments rest.

The only classification of this complex which is practicable is an arrangement according to a very rough and arbitrary scale of metamorphism. It is also necessary at present to distinguish between the southern frontier belt south of 6° N. and the rest of the Sudan, for the rocks of this are not strictly comparable with those of the north.

In the Northern Sudan, beginning with the most severely metamorphosed types, the following may be recognized:

1. (*a*) crystalline schists, gneiss, highly foliated and recrystallized apparently containing and interbedded with
   (*b*) schistose parametamorphic rocks such as limestone, graphite-slate or phyllite, quartzite and arkose, rhyolite and other volcanic rocks, and
   (*c*) slightly metamorphosed pelites, calc-pelites also interbedded with graphite-slate, quartzite, and limestone.
2. Highly crystalline banded foliated or foliated-granoblastic medium to coarse acid gneiss; these are mostly intrusive, granitic to granodioritic.
3. Intrusive igneous rocks, acid, intermediate, basic, ultrabasic; these are not completely foliated throughout their outcrop, but partly

[1] It is suggested that this section be omitted by readers unacquainted with geological nomenclature. See summary on p. 95.

foliated, especially on the margins: the basic and ultrabasic rocks in particular show a very wide range, from fresh types (gabbro and norite with or without olivine to hornblende-plagioclase-gneiss, dunite, pyroxenite, &c., to serpentine, actinolite-schist, talc-schist, and carbonate rock or Baramia rock of Hume).

4. Non-metamorphic sediments of the greywacke facies occur in the north-east Sudan only, associated with volcanic rocks (predominantly andesitic); these continue into Eritrea.

5 and 6. Non-foliated granitic intrusions of which the soda-granites are the latest; the non-foliated basic and ultrabasic rocks are excluded from this group until an example has been found cutting 4 above.

The crystalline sedimentary rocks cannot yet be arranged in groups or in a stratigraphical order. Structures appear simple. Foliation and bedding appear generally parallel, and the strike is constant over a very wide area (common variations in parentheses):

Northern frontier and SE. Egypt	ENE.–WSW. (E.–W.)
NE. Red Sea Hills N. of 18° N.: variable, no predominant strike	
Eritrea, N. . . .	NNW. by N.
S. . . .	N.–S.
W. Abyssinia . . .	NNE. by N. (N.–S.)
Central Sudan, Kordofan, Darfur, and W. Equatoria	NNE.–SSW.
Equatoria S. of 6° N. .	NNW.–SSE. (N.–S., NNE.–SSW. in west)

Attempts have been made to fit the basement complex of Egypt into a classification, endow it with a nomenclature, and to correlate the groups distinguished with other areas. At present, however, it is not possible to construct a general classification based on significant stratigraphical observations, except in very general terms for the non-metamorphic greywacke-lava succession, which can be identified in scattered large outcrops throughout the Red Sea Hills (Egypt to north Eritrea). The divisions given include both intrusive and sedimentary phases. The division into five phases implies folding and metamorphism as follows:

i. Deposition.
ii. Intrusive phase.
A. Folding and metamorphism of foregoing.
iii. Intrusive phase, followed by some folding (metamorphism).
iv. Deposition.
B. Folding, metamorphism negligible.
v. Intrusive phases (probably more than one).

Erosion-phases not specifically identified.

The nomenclature to be adopted cannot now attain any great precision. It will probably grow as local successions are distinguished under local

names or other indices. Hume's four divisions are very approximately equivalent to the groups given above:

Protarchaean i and ii.
Metarchaean i (in part).
Eparchaean iv.
Gattarian v (with most of iii).

The term 'Archaean' may be used for metamorphic rocks whose relationships and succession cannot be elucidated by ordinary sedimentary-stratigraphical methods in the field and which cannot be mapped on a broad scale. Stratified rocks, volcanic or sedimentary in origin, are best described by local names.

A comparison is possible with a recent stratigraphical scheme for eastern Africa south of the Sudan (Stockley, 1943):

	Sudan and Egypt	*E. Africa*
Pre-Cambrian	Not recognized	Bukoban
	Not recognized	Muva-Ankolean
	Greywacke-volcanic succession (Hammamat, Dokhan Series)	Kavirondian Nyanzian
	older basement complex	Basement System
Archaean	?	Not recognized

The basement complex of the southern part of Equatoria consists of a peculiar group of granoblastic-foliated basic to acid gneisses with hypersthene and transparent felspar intruded into foliated paraschists and paragneisses. The hypersthene-gneisses belong to the charnockite series which also occurs in northern Uganda. Non-charnockite acid intrusions occur, generally strongly foliated.

The region has received very slight attention. Quartzite and marble (limestone) have been found forming features traceable for considerable distances and most of the gneiss is probably paragneiss.

Post-foliation intrusions are of felspathoid soda-syenite. These are not placed in the table of succession, as the age is not known. Felspathoid syenites have not been recorded in the Sudan north of 6° N., but occur at Arkenu in Libya (soda-granite at 'Uweinat) and in a few scattered localities in the eastern desert of Egypt, the last attributed by Barthoux to the upper Cretaceous.

The basement complex forms over two-thirds of the rock-exposures of the Sudan. From it are carved the hills and plateau of Equatoria west of 34° E., the Nuba Mountains and northern plain of Kordofan, the foothills of the eastern frontier, the Red Sea Hills, and the eastern plain lying between the Red Sea Hills or eastern frontier and the Nile. The plain from which the volcanic range of Jebel Marra rises is also of basement complex.

The hills, whether in groups or isolated, have the inselberg form; steep sides and sugar-loaf summits are characteristic, formed of the tougher rocks which lack close-set planes of fissility or closely spaced jointing. The younger granites, especially the soda-granites, are conspicuous; lines

of hills are formed by quartzite, rhyolite, or occasionally graphitic slate (Lydian stone), and serpentine or gabbro (including norite) is usually prominent.

Marbles are common in the north-east, central, and south-west Sudan, associated with quartzites and graphite-slate (the latter is not recorded in the south-west), but rare in Darfur and east Equatoria. Many of these marbles are dolomitic.

Summary. The platform, on which the bedded sedimentary rocks lie, is a slightly irregular surface carved from folded metamorphic rocks, generally foliated, intruded by both foliated and non-foliated igneous rocks.

This basement complex is predominantly crystalline and felspathic, but a few obvious sedimentary rocks occur locally, such as limestone (marble), slate, and quartzite.

Table of Basement Complex succession

Sudan N. of 6° N.

6. Soda-granites
5. Unfoliated granites, &c.

B. Folding of non-metamorphic succession

4. Unmetamorphosed greywackes and lavas (predominantly andesitic)
   Folding and regional metamorphism (? **A** continued)
3. Plutonic intrusions: ultrabasic rocks (serpentines, &c.), gabbro-norites, granodiorite, granite, all more or less foliated

A. Folding and regional metamorphism

2. Oldest plutonic orthogneisses
1. Regionally metamorphosed paraschists, containing many slightly-metamorphosed bedded rocks, including lavas

Sudan S. of 6° N.

Felspathoid soda-syenites (possibly post-Palaeozoic)
Non-charnockitic foliated granites and granodiorites
Intense regional metamorphism
Charnockitic orthogneisses, parametamorphic succession

7–8: *The quasi-horizontal sedimentary succession* (*mainly Mesozoic*)

The sediments thus grouped together include deposits of 'continental' type, generally devoid of marine fossils. Outside the Sudan, however, they contain subordinate marine intercalations. They lie on a platform eroded from the folded rocks of the basement complex. These deposits are unmetamorphosed and have not been folded. They lie horizontally or with gentle dip on the basement platform, which is smooth and plane over wide areas, but locally has marked topographical features often of the steep-sided inselberg type which were buried under the young sediments. This irregular platform has been observed in Nigeria, in Egypt, and in the Sudan.

Owing to the absence of significant marine fossils and the tendency to lateral variation and vertical lithological monotony in this succession, exact stratigraphical correlation over wide areas is possible only on general grounds and is incapable of achieving precision at the present stage of knowledge. The information gathered from the fossiliferous rocks, including plant-remains, shows that these formations represent a range from the upper Palaeozoic to the upper part of the Cretaceous.

These sediments, predominantly arenaceous with interbedded finer-grained mudstones, shales, or clays, correspond to the Karroo system of South Africa. The Karroo terminology extends in a satisfactory manner as far as Entebbe in Uganda and to French Equatorial Africa. In North Africa it has been customary to use a nomenclature based on correlation with the European succession, because of the more frequent recurrence of marine fossiliferous sediments in the succession.

In the Sudan and in the eastern part of the French Sudan there is a minimum of fossiliferous intercalations, and a somewhat meagre succession now remains as a result of a combination of non-deposition and recurrent erosion.

So far no marine fossils have been found in the quasi-horizontal sediments of the Sudan and a few plant-remains which have been obtained are, with a few exception, either indeterminable or provide only approximate grounds for correlation. Very little systematic collection at the known fossiliferous localities has been done.

The occurrences observed in the Sudan are:

8	Nubian Series	north of 10° N.
	Yirol beds	south of 10° N.
7b	Carboniferous sandstones NW. frontier.	
	Lower Palaeozoic sandstones of Ennedi and Erdi	
7a	Nawa beds, central Sudan	

7 a. The Nawa beds are gently-dipping non-metamorphic purple or olive-green arkosic grits and mudstones with a noteworthy proportion of detrital white mica. They are only found in wells and bores in the Kashgeil and Abu Habl basin, covered by superficial deposits. The state of compaction of the sediments is greater than that of the Nubian Series. This succession occurs between 12° 12′ and 12° 50′ N., 30° 00′ and 34° 50′ E., in three apparently disconnected areas separated by rocks of the basement complex (Andrew and Karkanis, 1945).

The Nawa beds were proved in bores at Semeih Station, to a depth of 447 ft. (136·2 m.), in an abrupt and steep contact, probably faulted, with a granite.

It is not known whether the soda-granites are intrusive into the Nawa beds.

On general grounds the succession is regarded as pre-Mesozoic and may be representative of some part of the Karroo.

7 b. Palaeozoic sandstones occur only in the north-west, north of Wadi Howar.

The sub-horizontal sandstones and pebble-beds of the plateaux of N'Délé and Mouka, attributed to the Karroo, closely approach the Sudan.

The correlation of these occurrences and those of Haute-Sangha is based on lithological and positional grounds.

Legoux and Hourcq show the outliers of sandstone south of the Wadi Howar correlated with the Siluro-Devonian group north of Wadi Howar. It is preferable to regard these as undated, since they do not differ from the Mesozoic sandstones of the Sudanese part of the Libyan desert (so shown by Sandford 1935).

North of the Sudan, marine intercalations of Carboniferous age are

known in south-west Libya (23° 30′–27° N., 10° 16′ E., Desio 1939, pp. 14–15, map), and in Wadi ʿAraba in Egypt and in central Sinai in latitude 29° N.; marine Jurassic intercalations occur north of this in Egypt (29° 30′ to 30° 40′ N.); in Libya Triassic fossils have been found near Tripoli, the Jurassic of Murzuch being a lacustrine phase in the sandstone Series (Desio, 1939).

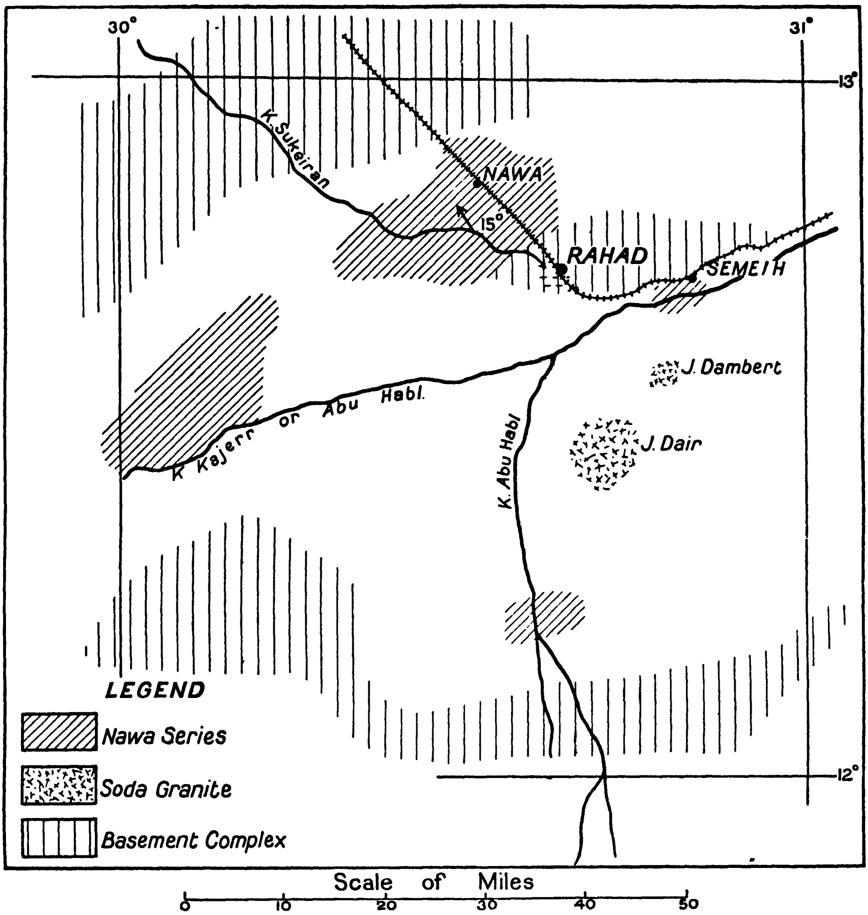


FIG. 31. Distribution of the Nawa series.

In the Sudan the Palaeozoic succession is represented by sandstones with a black shale intercalation, and is closed by a limestone (Sandford, 1935, p. 336) in Ennedi and Erdi:

Upper Palaeozoic	Grey limestone Soft light-grey sandstones Black sandstones, rippled White sandstones Hard black shales
Lower Palaeozoic	Massive sandstones with 'fantastic weathering'
	Basement complex.

These are overlain by Nubian (Mesozoic) variegated shales and mudstones.

North-east of 'Uweinat the succession is:

Plant-bearing sandstones (lower Carboniferous)
Rhyolite
Sandstone (? lower Palaeozoic)

Basement complex.

This section is capped by a conglomerate containing elements from all the older members of the section (Sandford, 1935, p. 339).

8: *Mesozoic Sandstones*

The majority of occurrences of sandstones of Nubian type in the Sudan are regarded as Mesozoic (cf. Sandford, op. cit., p. 335).

The sub-horizontal Mesozoic sandstones of the Sudan occur in three areas:

(i) The north-western area, a continuation of the Libyan sandstone region.
(ii) The eastern area, apparently continuous with the Abyssinian–Arabian–Somalian area.
(iii) A small occurrence of sediments of Nubian type west of the Bahr el Jebel; the Yirol beds.

East of the Sudan the sub-horizontal sandstones have a Jurassic marine intercalation, the Antalo limestone, in northern and central Abyssinia. The westernmost occurrence of this limestone is in the Abbai valley, 37° 57′ E. A limestone is recorded in sandstones in Khor Langeb (17° 16′ N., 36° 35′ E.) with chert, which is also recorded in the Abbai valley.

East of this the Jurassic marine part of the sandstones extends into Arabia and Somaliland.

The Sudan Nubian Series (*Cretaceous*)

The characters, thickness, and distribution of the Nubian Series in the north-west Sudan are described by Sandford (1935). The following summary includes the main points of this account and of the description of Lynes and Smith (1921) of the succession between Nahud and el Fasher.

Sandford identified a lower silicified sandstone and conglomerate bed in the Sarra region, middle shale and sandstone group of variegated colour and an upper buff and brown sandstone group, the whole succession being at least 150 m. thick, of which 90 m. is represented by the upper group. The middle group with mudstone floors the oases.

Farther south and east the lower beds are pebbly, but a basal conglomerate of diverse elements is confined to the Halfa area, to those occurrences overlying the Palaeozoic sandstones, and a surface 'shingle' of miscellaneous basement-complex rocks near Wadi Howar is interpreted as a basal bed to the Nubian Series in northern Darfur (Sandford, 1935, p. 349).

Intercalations of mudstones occur above the basal sandstones and ironstone beds, some of which are concretionary and some clay-ironstone beds without concretionary structure. These are interbedded with and surmounted by sandstones, generally not pebbly.

Silicified beds are common near the base of the series, especially as outliers capping hills of basement complex.

Fossil wood and plant-impressions are common near the base of the series. On low ground the base is usually obscured by drifted sand or scree.

The eastern occurrence is similar, but pebble-beds are relatively rare. Mudstones and ironstone occur.

The colours of the sediments vary from one bed to another; white, buff, ochre, chocolate, plum, dark brown, and occasionally vermilion, in streaks, spots, or evenly distributed in a bed. Grey is uncommon; the paler beds are often streaked with a pale lavender in patches.

No fossils other than plants have been found in the Sudan. Most of the plants are not specifically determinable; the silicified wood which is commonly strewn over the surface of the sandstone occasionally retains some cell-structure, and medullary rays and annular rings may be seen, also the butts of branches. Specimens are usually referred to *Dadoxylon*; most are identified as coniferous.

A collection from a basal silicified sandstone capping Jebel Dirra, east of el Fasher, has yielded identifiable fossils (Edwards, 1926):

Weichselia reticulata
Frenelopsis hoheneggeri
Dadoxylon aegyptiacum

These are of Upper Cretaceous type.

Shells of freshwater lamellibranchs were obtained (described by Newton, 1909) from the oolitic ironstone south of Aswan (*Unio humei*, *U. jowikolensis*, *U. crosthwaitei*, and *Mutela mycetopoides*) and from the west end of the Aswan Dam excavation a marine shell was obtained (*Inoceramus balli*) and marine worm-casts (*Galeolaria filiformis*) on a freshwater *Unio*. Russeger obtained *Cyclas fara* from Aswan, with dicotyledenous wood.

The Yirol beds are only known in well-sections, near Yirol and at Tali Post, north-north-west of Juba. The sediments have been proved to a maximum of 30 m. near Yirol and 22·8 m. at Tali, not bottomed in either case. The rocks of Nubian type include lavender mudstone and sandstone, ochreous ferruginous mudstone, pale-grey mudstone, white pipeclay, with little grit intercalation. They underlie the ironstone of the region and are patchily stained. The identification of these beds as Nubian Series is doubtful. There is no reason why a succession of sediments of Nubian type should not have been deposited and preserved in this down-faulted area at stages earlier or later than the Mesozoic. They are considered to be pre-Miocene.

The oft-repeated assertion that the Nubian Series is a desert or dune-formation is not supported by the occurrence of millet-seed sands or sandstones. Round-grained beds do occur, but they are very rare and are

not false-bedded. Sandford was convinced that the ripples and cross-bedding were formed by water, not wind (1935).

The succession was laid down on irregular land-surface and is thick in the former basins. It is everywhere sensibly horizontal. There are records of steeply dipping beds, but all come from small exposures on flat ground obscured by surface deposits. These occurrences cannot be interpreted as indicating movement, as they may be sections carved from false-bedding showing a high dip. Angular blocks of mudstones often occur in the sandstones, showing contemporaneous erosion.

Near Halfa a calcareous horizon is known, and the oolitic iron-ore of that region may be a metasomatic replacement of a limestone. A calcareous cement was observed in specimens from the Libyan area, between Jebel Tageru and Jebel Rahib (Grabham, 1928, p. 157). Limestone is also recorded, with chert, in the Khor Langeb faulted outliers.

9-12: *Tertiary and Early Quaternary.*

9: *The Hudi Series.*

The Hudi Chert was originally discovered in 1910 in the form of fossiliferous boulders at Hudi east of Atbara, and other bouldery occurrences west of the Nile near Zeidab were found in 1928. The second locality was visited later by Sandford (1933). Samples collected from Hudi were described by Cox (1932–3). Observations made lately have extended the distribution of this stratum (Andrew and Karkanis, 1944). The chert was found at Jebel Zaghawi (17° 17′ N.) at levels of 51 m. above the present Nile flood-plain and capping other hills, and also on Jebel Nakhara near Berber, overlain by 15 m. of sandstone, which is capped by a thin bed of reddened quartz-pebbles overlain in turn by basalt from an extinct crater, Jebel el ʿAtshan (Jebel Kisra or Arafabiya of the map). A similar extension was also found east of the Nile, between latitude 16° N. and 17° 30′ N.

The original bouldery masses of chert discovered in Wadi Hudi have travelled from a locality upstream; the masses found by Sandford on the plain appear from their size to be residual, and to have reached their present level by the removal of the underlying Nubian Series by normal denudation, the chert masses (with other cemented breccias) rolling or sliding down the hill-slopes after undercutting.

The Hudi Chert is a freshwater deposit, belonging to the uppermost part of the lower Tertiary (Cox, 1932, 1933), possibly Oligocene.

The fullest succession is seen on Jebel Nakhara, bedding horizontal:

				R.L. (m.)
Basalt, top of scarp, thin red pebble-bed with rounded quartz-pebbles			base at	369
Hudi Chert Series	red sandstone	15 m.	,,	354
	chert	2 m.	,,	352
Nubian Series	mudstone sandstone		seen to (base not seen)	346
Nile flood-plain level				326·16

The levels at which the chert now lies elsewhere are:

	R.L. (m.)
South of Debba (Hanakat el Kuleiwat) . . .	c. 325
On J. ez Zaghawi (17° 17′ N.; 51 m. above flood plain)	458
South-west of Dongola (17° 36′ N., 29° 42′ E.) . .	300
West of Dongola (19° 31′ N., 28° 56′ E.) . . .	300
West of J. Rahib (17° 50′ N., 26° 42′ E.) . . .	600
(Worked flakes W. of Laqiya at 490 m. R.L.) . .	—
North of the Khartoum–Kassala road. . . .	? 600

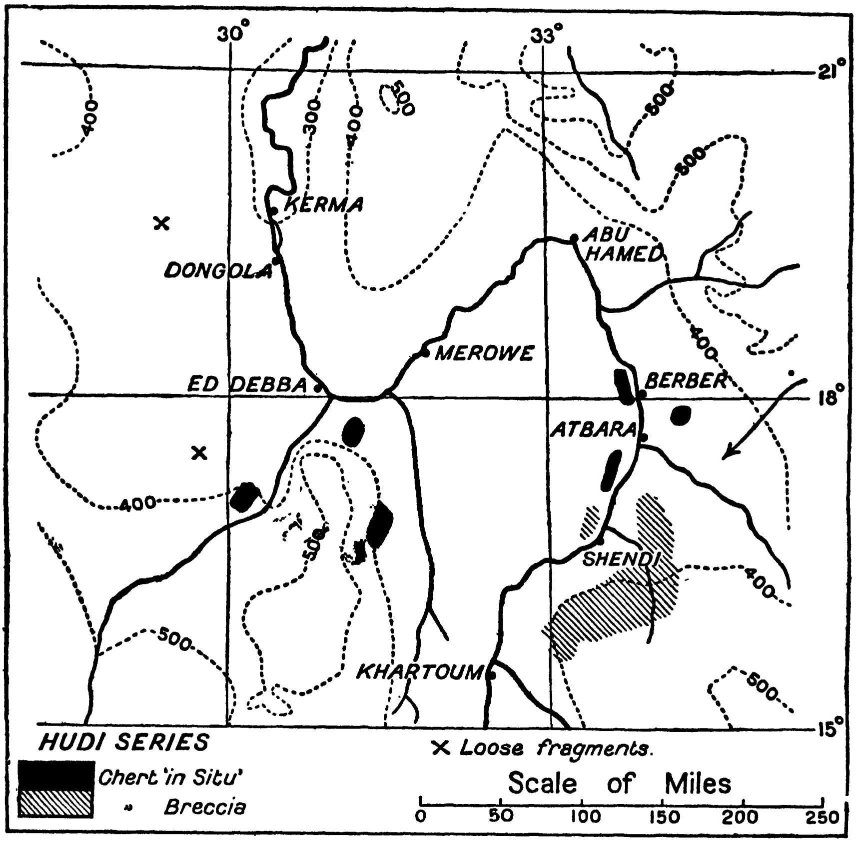


FIG. 32. Distribution of the Hudi Chert.

The later field-records were obtained by G. Yanni Karkanis and R. C. Wakefield.

The rock overlying the chert bed west of the Nile varies. There is a coarse ferricrete grit 30 cm. thick on Jebel Marfaibiya; a ferruginous grit with quartz-pebbles and ferruginous breccia or conglomerate containing chert-pebbles and quartz-pebbles on Jebel ez Zaghawi; a 15-metre bed of sandstone, with a reddened quartz-pebble-bed on top, underlying basalt, on Jebel Nakhara.

In the last of these localities the red quartz-pebble-bed has been traced beyond the limits of the chert and the Nubian Series, and so oversteps

all these and is probably unconformable to the Hudi sandstone. The further interpretation of these deposits is considered in the next section. The ferricrete beds west of Aliab and Zeidab have the same character as the porous ferricrete grits which cap the Nubian Series (see p. 103).

10: *The Lateritic Ironstone*

There is a widespread sheet of concretionary ironstone in a thick horizontal bed capping other rocks. In the north-western Sudan Sandford ascribed this ironstone to a lateritic phase in the middle Pleistocene, ending soon after the lower Palaeolithic stage (1933, p. 222) and preceding the 'qōz' or Kordofan sands (cf. Grabham, 1926, p. 281). Edmonds rejects the identification of these north-western ironstones with laterite (1942, p. 29).

In western Equatoria west of the Maridi-Yei watershed there is a concretionary ironstone sheet capping small hills at some 5–25 m. above the present-day plateau surface. In the Yei river basin a much higher remnant of a peneplain forms the Aloma plateau, south of Yei, also capped by ironstone. The present plateau is also covered by ironstone or red loam with soft red concretionary ferruginous pellets.

There are at least two peneplains, only slightly separated in some areas (e.g. Yambio; between Wau and Tonj; Rumbek–Mvolo–Amadi), widely separated in others (e.g. Aloma plateau, Kaia river basin between Loka and Kajo Kaji). The upper one is probably to be regarded as the mid-Tertiary peneplain, extending over most of the Sudan and represented only by scattered fragments. The lower peneplain, confined to the southern area south of 9° N., is undated.

Until local evidence is available no date can be assigned to this, nor is it certain that the lower ironstones constitute only a single stage.

In Oubangui-Chari Legoux notes the extension of the laterite to 13° N., disappearing farther north (1943, p. 61). In Eritrea Merla and Minucci found a marked ironstone horizon separating the sandstones from the lavas of the plateau (1938).

Provisionally the reddened pebble-bed of Jebel Nakhara and the ferricrete chert-breccia are correlated with this mid-Tertiary age of ferruginization. Silicification apparently was common at the Hudi Chert stage and also in the 'Oligocene' in Egypt (Cairo–Suez road, &c.).

As no ironstone is met in bores cutting the sediments of the depressions, but the infilling grits contain rolled ironstone pebbles and grains, the main and most extensive sheet is regarded as earlier than the Umm Ruwaba Series.

In identifying any particular occurrence of ironstone or example of ferricretion, the distinction between contemporary or recent concentrations of iron and an old 'fossil' concentration must be kept in mind (Edmonds, 1942). In the area occupied by the Nubian Series there is an additional complication in the occurrence of concretionary ironstone interbedded in the sandstone—mudstone series (e.g. at Wadi Seidna at 35 m. depth). The introduction of iron-concentrations into the Sandstone Series may have been the result of the mid-Tertiary 'lateritic'

climate. This ferruginization probably penetrated some distance below the mid-Tertiary land-surface in the sandstones. The same uncertainty exists in the silicified sandstones and the ferricrete grits.

There are two types of ferricrete sandstone to be distinguished. One is a porous grit in which the ferricrete matrix forms over 40 per cent. of the rock, the other a normal sandstone, with sand-grains in contact and a small amount of ferruginous cement.

The ferricrete (porous) grit is a surface rock, and is not found overlain by other strata of the Nubian Series; the ferruginous sandstone is an interbedded member of the Nubian Series. The grit resembles the ferricrete breccia containing Hudi Chert elements, and both are regarded as the representatives of the lateritic phase in sandstone country.

11: *The Volcanic Episode*

At some period following the lateritic ironstone volcanicity began on the top of the Abyssinia plateau and also along the Jebel Marra range to Matariq north-west of Kutum, north of Mellit as far as Meidob, and at scattered points east and south-east of the large volcanic mass of Emi Kussi in Ennedi.

The south-western region appears to have been free of volcanicity. In the Central Sudan there are scattered occurrences: the remains of a cone at Jebel Ahmed Agha, post-Nubian basaltic rocks near Omdurman and west of Atbara, craters north of the Gilif Hills to Berber.

Originally the Abyssinian lavas apparently extended farther north than the present continuous outcrop. Faulted outliers of lavas occur in the Langeb valley overlying the Nubian Series (17°+N., 30° 30′+E.).

The effect of this volcanic series is to raise the watersheds of the Marra range and the Abyssinian plateau to a considerable height above the pre-basalt surface, one result of which was probably to displace the isohyets of the region. Another effect has been the preservation by burial of the Hudi Chert and overlying beds. At present the lavas provide a fertile soil in the region they underlie and also in the valleys draining from the volcanic series.

The predominant rock is a basalt, but trachyte and phonolite are locally common (Marra range, Berti or Tagabo Hills). Pyroclastic rocks occur near craters.

Jebel Marra is a massive crater 5 km. in diameter with two crater-lakes, one saline (natron), the other fairly fresh, surrounded by walls mainly of ash and tuff; pumice occurs locally. Sodium carbonate and bicarbonate (natron) waters occur also at Malha (Meidob) crater, and in a crater-lake in the Bayuda volcanic area between Berber and Merowe. Natron also occurs in the lake at Merga (Nukheila), at Bir Natrun, and in a large area round 18° 33′ N., 26° 47′ E., north-east of Bir Natrun. No volcanic centre has been described near Merga and Bir Natrun, but they are within the area of feeble volcanicity, and the natron is probably due to juvenile waters.

The volcanic period is generally regarded as having begun in the Upper Tertiary (Miocene). Sandford points out that some of the craters present a very fresh unworn appearance, while other occurrences of volcanic

rock appear to have undergone considerable erosion (1935, p. 559). Volcanicity is known to have persisted feebly into historic times in the Red Sea, along the Abyssinian coastal plain, and in Lake Rudolf. Local vents on the top of the Abyssinian plateau have been active until very recent times, affecting drainage in the Lake Tana area. Volcanicity may have continued locally up to and even into the Pleistocene. There is so far no direct evidence on this point except the fresh appearance of some of the craters, Jebel Marra among them.

12: *Umm Ruwaba Series*

The existence of a deep depression west of Kosti and north of the Nuba Mountains is mentioned by Edmonds (1942, p. 28). He also suggested that flexuring associated with volcanic activity took place in Tertiary times, and that a general uplift took place in the Nuba Mountains region.

Andrew and Karkanis (1945) show the extent and depth of White Nile depressions, which were proved in 1914 by bores along the railway between Kosti and Umm Ruwaba, and later by bores at Taweisha and Muqlad west of the Nuba Mountains, by a well 25 km. east of Jebel Ahmed Agha, and by bores between the White Nile and the Nuba Mountains west-north-west of Kaka. Another depression is indicated in the Blue Nile basin by a bore at Khor el ʿAtshan station. These show that the floor (of basement complex) on which the superficial deposits lie is well below the level of rock in the White Nile valley north of Dueim and below the outlet of the Sabaloka gorge. The depressions have been filled in by deposits generally similar to the 'valley-fill' of the present desert area to the north.

The sediments consist of unconsolidated sands and clayey sands, some gravelly. The clays are mostly buff, but greyish-white and greyish-green clays occur. The sediments are generally unsorted, but some of the sand beds are devoid of clay. The minerals (felspar, biotite) are undecayed.

In the south, under the clay-plain east of the Sudd and White Nile, finer sediments occur. Those south of Malakal are fine well-sorted sands under the surface clays, and in the well east of Jebel Ahmed Agha the section is mainly of clays with rare intercalations of sand.

No significant fossils have been obtained from these deposits. At Umm Koweika (west of Kosti) at depths of 220 ft. and 305 ft. (R.L. 328 and 299 m.) fragments of the pectoral spines of a large siluroid fish and indeterminable fragmentary teeth were found. The pig-tooth (*Hylochoerus grabhami*; Hopwood, 1929) from Kosti comes from a depth of only 15 ft. below present river-level, in deposits of similar type but not necessarily of the same age.

The immediate significance of the deposits is much reduced by the absence of evidence of age; they are younger than the mid-Tertiary peneplain, and possibly extend well into the Pleistocene. They are older than the Kordofan ('qōz') sands and dark clays of the plain.

While the White Nile trough was being filled there could have been no escape of drainage north down the White Nile past Khartoum unless the infilling took place *pari passu* with the sinking of the floors of the depres-

sions. It seems probable that the drainage of the Blue Nile towards Egypt was never completely interrupted.

12–13: *Red Sea Deposits*

The accepted view is that the Red Sea was formed in the mid-Tertiary, post-Eocene, probably during the Oligocene.

It is probable that sediments, now deeply buried in the central trough, of Oligocene and Miocene age occur. So far no sediments older than 'Plio-Pleistocene', by analogy with those of the southern part of the Gulf of Suez in Egypt, have been found along the coastal strip of the Sudan.

These Plio-Pleistocene beds are of limestone, often shelly or coralline, shales, marls, clays, grits, conglomerates, and gypsum beds. They are overlain by Recent (raised) coral reef, and near the foothills by thick and very coarse angular river-terrace deposits.

The characteristic fossils are *Pecten vasseli* and *Laganum depressum*, with a small variety of lamellibranchs and gasteropods.

Dips are generally seawards, less than 3°, and are probably original. Local fold-structures occur and some faulting, with dips of 20° or more near the faults. In several places the series is intruded by basaltic sills or dykes. The thickness of the series, measured on low hills of the coastal plain, is over 100 m. (Jebel ʿEit) lying on basement complex, but it is fairly certain that the base is very irregular and a greater thickness would be found in bores.

A bore near Port Sudan reached a depth of 246·3 m., through a monotonous succession of clayey grits, of unknown age.

13: *Palaeolithic Terraces of the Nile*

Detailed work on the Palaeolithic deposits of the Nile valley has so far not been attempted south of Halfa.

At Halfa Sandford and W. J. Arkell (1933) found terraces or platforms at 91 m. and 61 m. without implements. A. J. Arkell has found pre-Chellean implements on the surface of a 45 m. platform, but the highest terraces which contained implements *in situ* are the 30-m. and 15-m. terraces (Chellean and Acheulean respectively). The Second Cataract was not developed until just after the Acheulean stage.

Erosion followed through the Levallois stage ('Mousterian' of Sandford and Arkell), but later aggradation set in and silts were deposited up to 30 m. in thickness below the Second Cataract, in the lower Sebilian stage. This was followed by erosion, the middle Sebilian stage being marked by a 20–22-m. platform, and the upper Sebilian by a 12-m. platform.

A later aggradation with silt-deposition is of post-Palaeolithic (post-Sebilian) age, followed finally by re-excavation of the channel in these silts.

Upstream of Halfa only scattered observations exist. Near Merowe A. J. Arkell found pre-Chellean implements *in situ* in a 51-m. terrace. Chellean tools occur *in situ* in a gravel just above high flood level downstream of Berber at Bouga, with Acheulean tools on the surface just above the Chellean. Between Sabaloka and Khartoum local gravels with Chellean and Acheulean artefacts *in situ* are at about 5 m. above the

present flood-plain. On the Atbara A. J. Arkell has found a rolled Chellean implement on a 5-m. surface near the Butana bridge. Wayland has apparently recognized implements farther north (1943, p. 334) at Sarsareib.

On the Blue Nile near Singa A. J. Arkell reports implements of Nanyukian or Kenya Fauresmith type from calcareous gravelly sands in the river bed, bared at low stage. These sands usually underlie the clays of the plain and are here covered by 30 ft. of heavy dark clay. The locality and horizon is that of the Singa 'protobushman' skull and a variety of mammalian bones. The age probably corresponds broadly with that of the post-Acheulean or 'developed Levallois' stage of the northern region.

It is to be expected that terrace-levels may be disjointed in the Khartoum–Halfa reaches. As each cataract develops, the river upstream tends to grade on to it. Vanished cataracts may be traced where there are now slack reaches. South of the Sabaloka terraces have been recognized only on the western side of the river. In the aggradation zone there are none, e.g. Blue Nile, Khartoum to Roseires; White Nile and Bahr el Jebel, Jebelein to Juba. There are yet no records of terraces south of Geteina on the White Nile. There are no records of Palaeolithic implements from the terraces of the Bahr el Jebel (Juba-Nimule) or from the rivers of Equatoria. The Blue Nile (also Dabus and Didessa) has terraces above Roseires, but the only fact known is that gravels near Roseires above present river-level have very few of the lava (basalt) pebbles which are so conspicuous in the gravels of the present stream bed.

Before passing on to consider the clays of the plain and the 'qōz' or ancient dunes of the west, it is convenient to consider the Nile valley.

Hurst and Phillips suggest that the White Nile *sensu lato* is very ancient, because of its profile (1938, pp. 14–18).

Ball resuscitates the hypothesis of a lake in the central Sudan, fed by the Blue Nile, Sobat, Bahr el Jebel, &c., rising to near the 400-m. contour and finally drained by capture through the Sabaloka gorge at the beginning of the lower Sebilian aggradation phase (1939, pp. 68–84).

Huzayyin suggests that the régime of the river may account for the Egyptian Sebilian 'Abyssinian mud', and ignores the Lake Sudd hypothesis (1941).

The impounding of a lake until the lower Sebilian is not supported by any local evidence, but the depressions formed a check to free outflow of the Blue Nile and a greater check to the White Nile basin at an early stage.

There is yet no evidence to show whether flow at any stage failed entirely through the Sabaloka gorge, but it seems probable that the White Nile basin had no outlet north for a considerable time in the Pleistocene.

The profile of the White Nile is that of a broad region aggraded to the outlet-level. On this view the present White Nile is a young effluent which has yet had insufficient time to do more than establish its channel north over the clay plain, and also has too high an exit-level to lower its bed. The exit-level is determined by the erosive power of the Blue Nile, to which it is a tributary.

The aggradation of the White Nile basin is apparently the final stage of the filling of an internal drainage system. Assuming similar climate in

the Nile basin, but less rainfall in Abyssinia, it has been calculated (Hurst and Phillips, 1938, p. 17) that a 20,000-sq. km. lake could evaporate all the inflow of the White Nile basin plus half the present discharge of the Blue Nile. Ball's Lake Sudd rising to the 400-m. contour would have an area of 230,000 square kilometres (1939, p. 76), capable of evaporating all the present volume of the Nile basin south of 15° N. (op. cit., p. 78). It is suggested that the lake or marshes which ended when the 380-m. level was reached was capable of evaporating the inflow of the White Nile basin only, and that drainage began to escape from this basin after the deposition of the clay of the plains.

The absence of outcrops of lower Palaeolithic terraces in the aggradation area suggests that they are buried under the clays, and therefore the clays are younger. It is not yet possible to correlate the Sebilian silts of Egypt with the Gezira clays, since no Sebilian implements have yet been found in the Sudan aggradation-plain.

14–15: *Upper Pleistocene to Recent*

14. *Clays of plain; Kordofan sands = 'qōz' or fixed, surface-reddened dunes.* There is only the scantiest information on the more recent deposits of the Sudan. It is possible, of course, to build sequences and to fit these in with sequences established in contiguous countries, but to do this plausibly obscures the lack of the local evidence and produces a false currency for hypotheses which may raise difficulties for future research.

The relative age of the 'qōz' and clay of the plains has still to be proved. The clay of the plains will probably be shown to be late middle Pleistocene or early upper Pleistocene; it is younger than deposits with lower Palaeolithic implements and than the beds of freshwater limestone. The age of the Umm Ruwaba Series is also not precisely fixed; it is older than the clay of the plain and the 'qōz', but whether followed by these directly or after a long interval of time is not known.

The Facts. A. The 'qōz' is an accumulation of dune-sand consisting almost entirely of quartz-grains. Edmonds regards it as derived from the Nubian Series. The dunes are now stabilized partly by a shallow and slight surface-cementation by iron oxide or a little clay, partly by vegetation. The 'qōz' is spread over the low ground of the west central Sudan (Darfur and northern Kordofan). Where the 'qōz' is in the form of a thick extensive sheet with an undulating surface there is very limited surface drainage because rain is absorbed, and earlier drainage-lines are obliterated or dammed (as at el Fasher), often forming a shallow seasonal lake ('rahad' or 'fula') puddled by silt. During the early stages of the 'qōz' period, lakes were more common than at present; there are deposits of shelly freshwater limestone and diatom-beds interbedded with the lowest 'qōz' sands in many parts of Darfur and northern Kordofan (cf. Chad and lakes in Tibesti; Raeburn and Jones, 1934, pp. 26–7, 59–61; and Legoux, 1943, p. 61).

The limits of the 'qōz' to the north are found near Guroguro on the frontier (19° N., 24° E.) and at Wadi Howar farther east, according to Sandford (1933, p. 217). In the south it does not quite reach the Umbelasha river. East of the frontier the southern limit is about 10° N.,

west of the Nuba Mountains. 'Qōz' is known east of the White Nile in a small area near Kosti and farther south, north-east of Renk. It is here not in dune form but spread flat by rainwash. Fixed dunes of 'qōz' type occur both east and west of the Nile north of Khartoum.

The northern limit may be expected to be indefinite, as in the present arid belt the upper reddened layers of the old dune would be removed, forming a modern live dune-field.

The direction of the 'sēf' (Arabic, sword) lines of 'qōz' is nearly north-south throughout (cf. Edmonds, 1942, pp. 19–20).

B. The clay of the plains is heavy, dark grey to dark chocolate; it develops deep cracks in the dry season and contains nodules and near the river branching root-like cylindrical growths, of white to greyish calcium carbonate known as 'kankar' (or 'kunkar').

The name 'cotton-soil' has been used for soils derived from this type of clay and for the clay itself, but from the agricultural point of view this name is regarded with disfavour.[1] It is essentially an alkaline clay.

Outside the area of 'qōz', and generally south of latitude 16° N., the latest deposit in the Sudan is a dark clay of this type overlying the Umm Ruwaba Series in the plains, and overlying basement complex, Nubian Series or Tertiary lavas on the higher ground, e.g. within the outer ring of the Nuba Mountains (up to 700 m.), and in the Didessa and Dabus valleys in western Abyssinia. Some valleys of northern and western Darfur (Azum, Howar) have a dark cracking-clay floor. The clay is typically uniformly dark in colour to a considerable depth (over 4 m.) in many sections, without apparent bedding or lamination.

Clays of this type overlie alluvial sands, rarely gravelly, in the Blue Nile basin (the Gezira).

Comment. 'Cotton-soil', by which is meant dark cracking clay, is recorded over a very wide area south of the Sudan (East Africa).

Grabham's interpretation of the clays of the Gezira is that they are aeolian clays or loess (1934, p. 19) roughly contemporaneous with the 'qōz' or Kordofan sands. He emphasizes the following features:

(*a*) Distribution south-east of the boundary of the 'qōz' (1909, fig. 1, p. 267).
(*b*) Similarity to the Indian 'regur' (1909, p. 266), e.g. without stratification, containing kankar (kunkar), absence of fossils.
(*c*) Occurrence on a wide range of levels; Nuba Mountains up to 700 m., central plain 380–450 m.

The reddening of the 'qōz' is attributed to a lateritic climate of Pleistocene age (Grabham, 1926).

These arguments are summarized in a general account of the Sudan (1935, pp. 275–8).

Sandford states that there is 'cotton-soil' in Wadi Howar and north of Mellit and that, in the last locality, it is overlain by typical 'qōz' sand (1935, p. 369). He accepts the Pleistocene age of the laterite, and assumes that the dark clay of northern Darfur is contemporaneous with dark clays of the plain (cf. 1935, 1935, 1936).

[1] Reasons are given in the introductory chapter at p. 5.—*Editor.*

Edmonds shows the south-eastern boundary of the 'qōz' very near the limits of the clays indicated by Grabham (1942, fig. 2 p. 23), suggests that the 'qōz' is derived from the breakdown of the Nubian sandstones, and discusses the 'cotton-soil' (ib., pp. 26–8) and the age of the lateritic climate (op. cit., p. 29).

The aeolian origin of the clay is rejected and an alluvial or colluvial origin is proposed as an alternative. The clays are not regarded as contemporaneous everywhere; those east of the White Nile are older than similar clays in the khors of the Nuba Mountains (ib., p. 27).

There is some conflict of evidence on superposition. Edmonds states that the clays overlie sands with a sharp contact in the Nuba Mountains (1942, p. 26), and that there is no interdigitation or merging of the two sediments. Both Grabham (1935) and Edmonds agree that the clays appear to be younger than the dunes; Sandford's observation north of Mellit stands alone.

There is at present no satisfactory evidence of relative age. The sections which show superposition do not serve to settle the point, for marginal sections are of redeposited material, rainwashed dune-sands overlying clays and redeposited clay in wadis overlying dune-sands. The latter case is found in the area north and west of the Nuba Mountains where clay-bearing streams derived from the Nuba Mountains meet the margin of the 'qōz' area from which there is no run-off. The former case may perhaps be exemplified by Sandford's Sayyah (Mellit) section where run-off from 'qōz' accumulations round the Berti (Tagabo) volcanic hills descend on to a clay-floored wadi. The 'qōz' is not underlain by clays similar to those of the plain in any of the numerous bore- and well-sections in Kordofan and Darfur.

The hypothesis of a Quaternary ironstone or lateritic climate in the northern Sudan has been based on the occurrence of a gravel of coarse pea-iron forming a thick deposit south of Omdurman. Sandford accepted this as a Pleistocene laterite and correlated the ironstone of the north-western Sudan with the Omdurman occurrence.

The Omdurman occurrence is now regarded as a gravel composed of ironstone debris, derived from concretionary ironstones in the Nubian Series. Its redeposition is of middle Pleistocene age.

The deposition of iron oxide on present-day surfaces is considered to be a normal feature of the arid climate (cf. Edmonds, 1942, p. 29), distinct from lateritic climate and from the heavy ferruginization now attributed to the mid-Tertiary.

The age-relation of the clays of the plain to the Palaeolithic gravels has been settled by observation of superposition at Singa, where 'Kenya Fauresmith' artefacts occur in calcreted sands under the clays. Calcretion with the formation of beds of freshwater limestone is common in the sub-clay sandy alluvium of both the Blue Nile and White Nile basins and also in the gravels. The Sebilian silts near Kom Ombo (Daraw) contain abundant rolled and worn rods and nodules of freshwater limestone (kankar). If the mineralogy of these silts confirms the probability that they are derived either from the clays of the Sudan plain or from the same source as those clays, this may provide an upper date-limit to the

Normal downcutting occurs, in the Bahr el Jebel above Rejaf to lower the Nimule sill, in the Blue Nile above Roseires, in the Atbara above Khashm el Girba, and in the main Nile between Sabaloka and Aswan. The last has many alternating reaches of gentle gradients and cataracts or rapids.

In the White Nile basin from Mongalla to Khartoum stability of the present surface depends on the escape level; slow aggradation is proceeding in the swamps above Malakal and a fairly stable condition exists downstream of Malakal with aggradation in the area east of this reach along the Abyssinian frontier.

The stable condition is due mainly to feebleness of run-off and to the very small slope of the ground between Malakal and Sabaloka.

Shukri (1945) has, however, suggested that a metamorphic heavy-mineral suite in Nile sediments of Neolithic age near Cairo is derived 'from the southern countries' via the White Nile.

In the Blue Nile above the Sennar Dam an ancient series of meanders appears to depend on the former existence of a cataract, on which the dam is founded. The area has been aggraded over this barrier, for the rock-bar is buried under a thick cover of sediments. Downstream surface-levels continue the upstream slope fairly smoothly, after a slight increase in slope below the former cataract:

Mean valley slopes (eliminating meanders) based on low river levels:

	cm./km.
Singa to Sennar (upstream of dam)	19·71
Old Sennar to W. Haddad	22·33
Wad el Haddad to Hag Abdullah	22·93
Hag Abdullah to Medani	15·16
Medani to Kamlin	10·34
Kamlin to Khartoum	9·15

The incised valley of the Blue Nile, with clay banks which stand between 10 m. and 14 m. (Khartoum) above low water-level, is liable to erosion at a considerable rate. Some gullying above Sennar does occur, but it is partly prevented by the arrival of the flood before the rains provide much lateral run-off (Table I). Much of the earliest rainfall is absorbed where it falls.

North of the Sabaloka gorge the effect of rainfall is negligible, as only very rare local showers produce run-off which reaches the river; lowering of the banks is therefore at a minimum. The river is occupied in down-cutting over cataracts; between cataracts there is a tendency for deposition to occur locally.

The Atbara is roughly similar. There is a negligible run-off north of Qōz Regeb (Table II).

The Atbara and Blue Nile are floored by sand (gravel at Roseires), and this extends downstream along the main Nile. The floor of the White Nile is fine mud below Kenisa (Bahr el Jebel). The banks of the Blue Nile, Atbara, and main Nile are of clayey silts, deposited during the height of the flood. The White Nile banks are mainly of alluvial mud, nearly flush with the flood-level, or of the clay of the plain. Sandbanks occur in the Zeraf, and in the Bahr el Jebel upstream of Kenisa.

The present course of the Nile has formerly been discussed in relation

to possible movements which have affected the country; most discussions have assumed fold movements to explain the bends in the river north of Khartoum.

The general direction and position of the river is determined by the tectonic hollow or syncline which lies between the Red Sea Hills and the plateau of the western borderland.

Rainfall and Rise of River-levels

TABLE I

	Roseires		*Singa**		*Old Sennar*		*Medani*		*Khartoum*	
	1	*2*	*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*
March	0·09	1·8	4·59	tr.	0·10	..	0·12	..	0·17	..
April	0·00	15·2	1·64	4·8	0·02	2·8	0·02	3·6	0·02	1·0
May	0·56	62·6	0·31	34·3	0·28	24·6	0·34	11·5	0·15	3·9
June	1·86	128·9	1·62	71·9	1·19	57·1	1·65	33·2	0·89	9·0
July	4·82	186·8	4·85	164·8	3·45	121·9	4·71	132·3	2·75	53·7
August	7·75	218·8	8·08	190·9	6·29	165·3	8·25	145·2	5·28	74·2
September	7·08	150·7	7·76	85·2	5·89	67·5	8·15	54·8	5·47	18·5
October	4·70	33·7	5·44	28·6	3·79	19·6	5·60	13·2	4·02	4·3
November	2·64	5·0	5·30	1·9	1·95	1·0	2·95	1·0	2·38	..

TABLE II

	Showak†		*Khashm el Girba*		*Atbara*‡	
	1	*2*	*1*	*2*	*1*	*2*
March	..	1·8	..	..	..	..
April	..	5·8	..	..	..	1·0
May	..	26·4	..	15·8	..	3·1
June	..	100·9	..	43·2	..	1·8
July	1·64	185·9	2·14	150·6	1·59	18·4
August	3·87	204·3	3·53	155·1	3·92	38·1
September	2·52	105·7	2·71	69·0	3·80	5·9
October	0·33	28·6	1·04	9·8	1·94	2·1
November	..	6·6	0·17	1·8	0·62	..

1 Mean monthly excess of level above minimum metres. The figure is the difference between the lowest 10-day mean gauge reading and the mean for the month quoted (see Hurst and Phillips, vol. iii, second supplement, pp. 242–53).

2 Mean monthly rainfall, mm. (1943).

* The levels are affected by the Sennar Dam, in which the maximum level is 420·70 during December and January; emptying begins at the end of January to a maximum at the end of May. The reduced levels of the mean water surface at Singa are: March, 419·03; May, 414·75; August 422·52.

† 1937 only; rainfall measured at Gedaref.

‡ On the Atbara no minima are available. The lowest 10-day mean is taken as zero.

Atbara 21–31 Dec. (9·97); Khashm el Girba, 21–30 Nov. (10·58); Showak 21–30 June (10·17).

The Sobat, Blue Nile, and Atbara systems are consequent upon the uplift of the Abyssinian plateau, with modifications introduced on that plateau by volcanicity.

The Bahr el Jebel is an overflow from the depression of the Lake

Albert rift valley. Very little is known of the development of the rivers east of the Bahr el Jebel. The more important of these (Aswa, Kidepo) now rise in the Karamoja plateau.

The rivers of western Equatoria are slightly incised into a mature peneplain, rejuvenated after the deposition of the ironstone. This area drains towards Lake No. The Kaia river joining the Bahr el Jebel between Nimule and Juba is well incised into this peneplain, and the Luri river is similar; nothing is known in detail about their development.

The Bahr el Jebel follows an obvious structural line for over 100 km. from Nimule, but below this it wanders away from the scarp and below Rejaf enters a broad aggradation-plain. From Mongalla to its junction with the Blue Nile the course of this river appears to be determined by deposition of sediment by tributaries and it is probable that the course of the Bahr el 'Arab is also determined thus, the low point being fixed by the (former) activity of the affluents on either side which now fail to reach the river. The White Nile from Jebelein to ed Dueim bears against rock on the right bank; from Dueim downstream to the beginning of the rock-bound valley near Sabaloka the valley bears against rock on the left bank, the right being a part of the Gezira clay plain.

The Blue Nile valley below Roseires lies towards the left side of the alluvial plain; rock is met at moderate depths west of the river, but is at greater depth to the east of Sennar.

On general considerations the most reasonable interpretation of the plain above Sabaloka is:

(i) the original plain was produced by long-continued erosion since the last regression of Cretaceous age continuing until

(ii) downwarping of the erosion-surface set in. This may have begun in mid-Tertiary times, and have continued intermittently into the Pleistocene. During the downwarping sedimentation occurred south of the Sabaloka in the depressions formed.

(iii) The present stage is the result either of the cessation of warping or of its slowing down to allow sedimentation to maintain the surface at levels which allow very little ponding of water.

There is evidence to suggest that (*a*) some downwarping has occurred as lately as the middle Pleistocene, and (*b*) that the White Nile has only lately succeeded in discharging north into the Blue Nile system.

The Sabaloka gorge was interpreted by Hume as a superposed valley, as no tectonic line of weakness could be seen and the hills appeared to have been originally covered by the Nubian Series (Lyons, 1906, p. 236). Grabham supported this reading (Sandford and Arkell, 1935, p. 24, footnote).

Downstream there appears to be a general tendency for the river to flow over the basement complex in a course which must have originally been formed in the Nubian Series. The reach from Dongola to Halfa only approximately follows the base of the Nubian Series; the river crosses from basement complex to flow over the Nubian Series between Shendi and Atbara and again between Merowe and Dongola. The reaches in which it lies on basement complex may be determined by very

shallow folding, but the appearance in outcrop of the basement complex in these reaches is probably due to broad swells of the floor of the Nubian Series which were already there when that series was deposited.

The effect of the volcanic rocks and of movements accompanying the eruptive phase are the most obvious influences which may have produced the Abu Hamed to Merowe bend. The remnants of this volcanicity occur west of the river at Omdurman, between Atbara and Berber, and astride the river north of Dongola. There are no records of Tertiary volcanic rocks east of the river, except for some cone-like or crater-like hills east of the railway between Abu Hamed and Halfa, seen from the air only. These volcanic accumulations, spread over a plain formed of fairly soft sandstones and mudstones, were probably enough to deflect the river's course. The volcanicity of the Bayuda field between Berber and Merowe is marked by obvious craters and has a very modern look. The lavas of Omdurman and Atbara and those of north of Dongola are now represented by sheets and plugs in the Nubian Series unaccompanied by the typical surface forms (craters, &c.).

The Red Sea Hills drainage shows a highly developed stage of river-capture. The steep fall east to the sea has enabled many streams to capture the heads of streams graded on to the Nile and a variety of stages of this may be seen. The streams flowing to the Red Sea have very irregular slopes, and many debouch on to the coastal plain through a steep-sided gorge. Some sections of the valleys are very straight, and it is probable that these lie along fault-lines.

The valleys were apparently well developed early in the Miocene (Beadnell, 1924, pp. 15–19, 33). They are now choked with debris and alluvium except in some of the short gorge-sections, and the coastal plain has a fairly steep slope on the surface of subaerial deposits from both the major and the minor wadis.

Profiles are not known in detail, but a few heights determined in Khor Arba'at and levels along the railway from Port Sudan afford an idea of the type of thalweg. In Khor Arba'at the points at which heights are given do not correspond with the points at which change of slope occurs.

	Distance km.	*Slope (cm./km.)*
Kh. Arba'at		
Head of Kh. Tibiramfi to Kh. Kwish	95	460
Kh. Kwish to Kh. Yas	13·5	940
Kh. Yas to a point R.L. 1,000 ft.	27	393
1,000 ft. point to house of gorge	12	700
House at gorge to wells	15	707
Wells to sea, N. branch	21·5	535
" " S. branch	24	479
Kh. Tutali to Adit (railway)		
Summit to Sinkat	9	656
Sinkat to Gebeit	15	413
Gebeit to Kamobsanha	39	784
Kamobsanha via Kh. Tutali to Obo	12	1,342
Obo to sea, via Kh. Okwat	34·5	980

Slopes of the older Nile drainage are gentler and more regular:

	Distance km.	*Slope (cm./km.)*
W. 'Arab		
Erkowit to Summit	33·6	711
Summit to Haiya junction	74	372
Haiya to Shediyeb	37	230
Shediyeb to Musmar	46	141
Musmar to Togni	47	177
Togni to Atbara (aggradation plain)	175	35
W. Howar		
Watershed to Tini	24	167
Tini to R.L. 670 m.	240	63
R.L. 670 m. to R.L. 374 m..	160	85
R.L. 374 m. to S. of J. Rahib (present end of wadi).	144	42
(*S. of Rahib to Dongola no trace*	*400*	*74*)
Kh. Abu Habl		
Dilling to Rahad	140	128·6
Rahad to Umm Ruwaba	73	64·4
Umm Ruwaba to Tendelti (present end of wadi)	72	43·1
(*Tendelti to Kosti, no trace*	*93*	*37·6*)

An idea of ground-slopes may be deduced from the 10-day mean minimal levels of the river at gauge sites and the mean-line distance (ignoring convolutions of the river) between gauge points (see Hurst and Phillips, *The Nile Basin*).

	Distance (km.)	*Ground-slope (cm./km.)*
Cairo to the coast due N. of Cairo (Ball, op. cit., p. 47)	170	9·41
White Nile	*Mean line*	*Low stage river, slopes*
Terakeka to Bor	85	16·73
Bor to Kenisa*	83	11·27
Kenisa to Ghaba Shambe	50	9·71
Ghaba Shambe to L. No.	260	7·29
Downstream of L. No. to Mogren	826	never more than 3·2
Sobat		
Pibor mouth to Abwong	134	8·21
Abwong to Sobat mouth	78	1·24
Bahr el 'Arab		
Meshra er Req to L. No.	180	1·14
Blue Nile		
Wad Medani to Kamlin	83	10·34
Kamlin to Soba	82	9·70
Soba to Khartoum	18	3·06
Khartoum to Mogren	4	1·25

* Sandbanks fade out from Kenisa downstream.

It is clear that these slopes are those of an aggradation-plain or delta, comparable with slopes below the last cataract (Ball, 1939, pp. 70–4, fig. 13), and particularly with those of the delta from the lowest barrage to the sea.

The Soils of the Sudan

The notes on Pleistocene geology of the Sudan indicate the background in which the soils have been developed.

The superficial deposits may be divided, according to age, into the following groups:

I. Tertiary sediments, sub-ironstone clays where exposed, ironstone.

II. Pleistocene sediments:
   i. Umm Ruwaba Series, rarely exposed.
   ii. Sands and gravels underlying the clays of the plain, rarely exposed.
   iii. (*a*) Kordofan sands, fixed dunes.
   (*b*) Clays of the plain.
   iv. Red loams and unconsolidated ferruginous clays of W. Equatoria.

III. Recent deposits:
   i. Valleys deposits, alluvium, varying with position in thalweg and also with the position of the valley in relation to the isohyets.
   ii. Dune sands (modern).
   iii. Modern soils overlying parent rock roughly *in situ*:
   (*a*) from varieties of the basement complex;
   (*b*) from the Nubian Series;
   (*c*) from the Tertiary lavas.

This classification serves to emphasize a point which has received too little attention: that much of the material from which a soil develops is unconsolidated and weathered, and that the climatic conditions under which this weathering took place were not necessarily those of the present day.

The deposits of Tertiary ironstone were derived by weathering from the local rocks (in western Equatoria the crystalline basement complex) upon which they are now found, and are clearly *in situ*. The sub-ironstone clays often contains relics of the rock-structure undisturbed, and so do the ironstones.

The red loams and unconsolidated ferruginous clays of western Equatoria, here attributed to a later Pleistocene lateritic phase, are similarly *in situ*.

The modern soils (III. iii) are derived from weathering under present-day climate, also *in situ*.

The remaining unconsolidated deposits which form soils, of which the most important are the late Pleistocene sediments (II. iii) and the Recent deposits of the plains (III. i and ii), are all transported sediments, at some distance from their source. It may be assumed that the upper layers of the Recent deposits are the natural products of the present climate, but this is not necessarily true of the older strata.

I. The sub-ironstone clays are not widely exposed. They are found in valleys cut in the ironstone plateau of western Equatoria, often as a thick deposit of white kaolin with residual muscovite and quartz (Yambio, Sources Yubo), or in the form of a pale sticky clay with scattered sand-grains, exposed by the removal of the ironstone along the flanks of streams. The deposits do not contain ironstone grains as detrital material, although they may be stained and mottled by iron-oxide precipitation under present-day conditions. This feature serves as field-aid in distinguishing between modern alluvial sandy clays of the present valley.

The ironstones form a capping to flat-topped hills, and to the higher plateau. Some consolidated ironstones may have been formed more recently. Some of the ironstones appear to be a hardened fringe to the red loams and ferruginous clays where these have been exposed by erosion, as a result of drying out in the dry season. The small scarps or banks of ironstone which flank the valleys are probably of this type. Regarded as soil-forming rocks they give the same type of soil as the older Tertiary ironstone.

II. (i) The Pleistocene sediments of the Umm Ruwaba Series are not known to form any extensive outcrops, and may even not appear at the surface at all.

(ii) The sands and gravels of the plain appear to form low banks ('debba') in the White Nile plain. There is a sandy ridge, described originally by Stevenson-Hamilton (1920) as the Duk ridge, which may be an outcrop of a pre-clay deposit (i.e. not now covered by younger clay). There are similar patches of sandy soil in the 'Southern Gezira' (south of the Sennar-Kosti railway).

(iii) (*a*) The Kordofan sand covers a wide area in northern Kordofan and central and southern Darfur (Edmonds, 1942). The sands are free-draining, with some clay or ferruginous clay as a bond near the surface, making them firm after rains. Little surface drainage is developed in the country which is entirely covered by these dunes, but 'rahud' (pools filled by rain), floored by a thin skin of clayey deposits, are common in hollows.

The sands are peculiarly poor in minerals other than quartz. Edmonds suggests that they were derived from the Nubian Series to the north.

(iii) (*b*) The clays of the plain are the most important of all the soil-forming deposits in the Sudan. They are considered to be mainly alluvial in origin, but some may be *in situ*, e.g. the basaltic clays round Gedaref.

At present these clay deposits are still forming in those areas subject to widespread flooding during the rains, in and round the Sudd area, including the lower part of the Sobat and Pibor rivers, and the western limits of drainage from the higher ground between the Sobat valley and the Blue Nile.

In the rest of the area, particularly in the Nuba Mountains, and in the northern clay plain between the White Nile and the Abyssinian–Eritrean frontier north of the latitude of Roseires, the clays are either stable or undergoing removal by normal erosion to lower levels. A relatively moderate proportion reaches the flooded rivers.

The source of the clays is attributed to the hills which now discharge drainage on to the plains—the basement complex plus ironstone plateau in Equatoria; the basement complex plus lavas of Abyssinia and the frontier-zone south of the Setit river; the basement complex in the Nuba Mountains.

The features of the clays which have an important bearing on their soil characteristics are:

(i) Fine texture, generally over 60 per cent. clay fraction ($<0{\cdot}002$ mm.).
(ii) Alkaline reaction, pH high, correlated with the abundance of easily decomposed minerals such as pyroxene, amphibole, biotite, felspar, together with relatively poor leaching by surface water.
(iii) Thickness, demonstrating constant conditions of deposition over a considerable period.

Examination of these clays has so far not been extensive or in detail outside the Gezira, and much remains to be done, especially on the mineralogy and fossil contents of the clays.

Discussion of the conditions of deposition, which will throw considerable light on the distribution of types and aid in the making of the soil map, cannot yet be more definite than that given in the Soil Conservation Committees' Report (Appendix XXV, 1944, pp. 151–3).

The age of the clays appears to be between the Levallois stage and early dynastic times, perhaps limited to some stage of the Sebilian. Further work on the Nile valley south of Halfa is required before any precise correlation is obtained.

The Blue Nile valley was subjected to floods during the deposition of the clays, but was not the site of a permanent lake (see above, p. 110; also Tothill, 'Origin of Gezira Clay Plain', *Sudan Notes and Records*, vol. xxvii, 1946). This is demonstrated by the molluscan remains. The floods must have consisted of a relatively gentle inundation, for the quantity of sediment above clay-grade in the clays is small. The clays in the Blue Nile valley (Gezira area) were partly derived from the lavas of Abyssinia, partly from the basement complex which provided sediment upstream of Roseires, particularly from the Didessa and Yabus valleys. The lava-mineral group is preponderant (Shukri, 1945) and fresh. This appears to indicate a fairly arid climate, under which soils formed on the high plateau were swept away in abundance in the seasonal heavy rainfall, rather than a humid climate with continuous rainfall. The Blue Nile at present carries fine silt and clay mainly, and sands forming banks and the floor of the river include fresh material reinforced by coarser sediment derived from the sands underlying the clays, with a negligible addition by tributaries of fresh materials other than clay downstream of Roseires (say north of $12^\circ 25'$ N.). Conditions for clay deposition on the scale of the Gezira plain demand a slightly increased rainfall during the summer months on the highlands, but a climate not greatly different from that of to-day.

The depressions observed in both the Blue and the White Nile valleys (Andrew and Karkanis, 1945) account for the flatness of the present plain. There is a suggestion that the depression in the Blue Nile basin was still forming in the middle Pleistocene, as the elephant tooth found under the

caisson of the Blue Nile bridge at Khartoum was found in sands and gravels at a level below the probable outlet-level of the middle Pleistocene Nile at Sabaloka.

The slow formation of this depression would partly account for the broad spreading of clays over the Gezira plain. This requires to be checked by study of the Pleistocene sediments, but it is known that Blue Nile sediments extend as far as the left bank of the White Nile at Jebel Auliya, and into the central part of the Gezira plain, midway between the Blue and White Niles in latitude 14° 45′ N. The southern limit of Blue Nile sediment in the White Nile valley south of Khartoum has not yet been exactly ascertained.

Little is known of the larger White Nile clay plain, which extends from the Abyssinian frontier south of Roseires to the western side of the Nuba Mountains, south of the Sennar–Kosti railway to the south of the Sobat and round the edge of the Sudd swamps.

The uppermost sediments of the Sudd fringe in north-west Equatoria, south of the Bahr el 'Arab, and that of the plain between the Uganda frontier and the swamps south of the Sobat, contain much cracking clay in the swamp-region.

Near the active streams along the fringes of the foothills a mixed sandy-clay deposit is clearly of Recent formation. It may therefore be assumed that the formation of the clay-plain is still proceeding in the swamps of the White Nile valley, and that where this is occurring the exposed clays of the plains south of latitude 10° N. are younger than the exposed layers in the Blue Nile (Gezira) area. Edmonds made this suggestion in a tentative fashion in the course of his discussion of the Kordofan sands (1942, p. 27), but did not enter into details.

(iv) The red loams of western Equatoria form a thick cover on the low plateau in which the streams are increased in shallow and relatively narrow valleys.

These often have a rim, parallel with the valley sides, of hardened ironstone, considered to be formed as a result of the drainage of the free edge of the nearly flat ferruginous loam cover.

These red loams, which frequently contain soft pisolite-like concretions of bright red ferruginous clay, are derived by lateritic weathering from the subjacent rocks. On the plateau they are frequently over 3 m. thick and may reach nearly 5 m. in depth.

It is considered that these lateritic loams are the product of an earlier (Pleistocene) lateritic climate, not a result of present-day conditions. They are now being removed slowly by present-day erosion, of which the hardened ironstone edge is a feature.[1]

III. *Recent Deposits.* Elements of all the pre-existing deposits contribute to the Recent deposits of the Sudan, but the widespread unconsolidated superficial deposits contribute the major part of the valley deposits.

(i) The 'valley-fill' of the arid area, within the isohyet zone 0–300 mm. rainfall, is a clayey, often gravelly sand or grit when derived from the

[1] These Pleistocene laterites should not be confused with the older mid-Tertiary laterites.

basement complex, with a top dressing of clay or silt in patches on the valley floor. In the valleys draining the Nubian Series it is a clayey grit or sand, with a few pebbles. derived from the Nubian Series, of quartz and other tough (ferricrete or silcrete) rocks. In the valleys draining the lavas the characteristic deposit is a dark sand, with heavy dark clays where the stream runs slackly in flood.

The silts of the Gash Delta (Kassala) and the Baraka Delta (Tokar) are derived from an area of basement complex.

The Recent deposits of the Blue Nile valley and the main Nile below Khartoum are clays of the same type as those of the plain, but with more sand and silt brought down by the flood.

The Wadi Ku is typical of the drainage from the Darfur Nile–Chad watershed, with clayey silts derived partly from the lava capping on the watershed and partly from the subjacent basement complex. The Nubian Series and the dunes contribute a little sand on the east side of the range.

In western Equatoria sands form the floor of the river-beds, except in the upper reaches where beheaded streams develop small patches of papyrus swamp on a clay floor. Near the mouths of the valleys, where these open out on to the plain which becomes a waterlogged swamp in the rainy season, the valleys are wide and flat, filled with a thick series of clayey sands on which rests a more or less clayey layer a few inches to a couple of feet thick (e.g. Wau, Rumbek).

This is the 'toich' country. The term 'toich' (or 'toic') appears to be based on ecological rather than geological character, for the Yirol 'toich' is of thick, heavy clay which does not resemble the majority of 'toiches'; it is floored by a thick clay deposit possibly of early Pleistocene age.

In eastern Equatoria the valley alluvium resembles the valley-fill of the northern arid area, with clayey margins to the plain against the hills.

(ii) Modern dune sands are not usually in the area of cultivation except as remobilized sand deposits where the surface has been denuded of vegetation.

The modern dunes, in contrast to the 'qoz' or Kordofan sand dunes, have no clayey or ferruginous bond, and have abundant ferromagnesian constituents as a rule. A little calcretion may occur.

(iii) The modern weathering products of the pre-Quaternary formations of consolidated rock, *in situ*, occur on the hills among outcrops of the parent rocks.

(*a*) The basement-complex soils appear in a general way to be similar between the southern frontier and latitude 12° 15′ N., in the Ingessana Hills, the Nuba Mountains, and on crystalline rock directly exposed without a cover of ironstone or red loam both east and west of the Nile in Equatoria.

(*b*) There are small areas of soils derived directly from the Nubian Series. These resemble the valley-fill of the Nubian Series area (III. (i) above), and consist of sandy buff clays. The Nubian Series mostly forms bare scrub land and more or less naked hills, or underlies the Quaternary deposits (II).

(*c*) The Tertiary lavas are mainly basaltic. Those of the eastern part contain a noteworthy proportion of zeolites. The soils are generally dark

loams or clay loams, similar to the Gezira clays. Little attention has been paid to these, but they are sensibly similar over a very wide variation in rainfall (Gedaref, Marra Mountains, Nagichot, Boma).

The conception of a soil catena, applied to the soils of the Sudan, is difficult to apply in a broad way. For the catena to have geological significance it must be applied to soils formed from a single rock group, the members of which behave uniformly as regards soil formation (see I. C. Brown and J. Thorp, *U.S. Dept. Agric. Techn. Bull.* 834, 1942, pp. 4–6), and also to soils formed under existing climatic conditions. The various profiles of a catena should be in equilibrium with current conditions.[1]

If the age-classification of the unconsolidated superficial sediments of the Sudan is accepted as a basis for classifying soils into catenas, then the ironstone, red loam, and the clays of the Gezira plains are 'fossil soils' or 'rocks' which give rise to soils. The clays of a 'toich' therefore have a mixed parentage, partly derived from present-day weathering of basement-complex and of ironstone plus red loam. The ironstone plus red loam is material weathered under different climatic conditions in an earlier time-period, and so undergoes nowadays a further change to bring it into equilibrium with present conditions.

The same applies to the clay of the Gezira, which is producing a soil which need not necessarily be identical with the Recent soil forming on exposed rocks in the area.

Water-supply

The problem of water-supply in the Sudan is a growing one. With a small population, kept low by disease and strife, with plenty of room to migrate, water-supply only becomes an acute difficulty if the migration is unfortunate in choice of route or is successfully opposed. With a growing population and increased settlement the problem of supply sufficient for the dry season becomes serious. High evaporation loss causes surface water to disappear at some stage of the dry season, except near the main perennial rivers and a few small permanent lakes. Underground supplies are necessary for a great part of the country, and where these are naturally scarce means are required of conserving surface-water as far into the dry season as is possible.

Underground supplies depend on both local geology and local rainfall, except in a few places where deep-seated supplies depend on rainfall at some distance from the natural underground reservoir.

In the northern desert region there are two potential sources of underground water. One is a permanent water-table in sandstones of the Nubian Series, often at considerable depth, but locally bared by erosion to form oases on a mudstone layer. The other is due to local concentration of subsoil water along discharge lines, derived from local rainfall and particularly supported by seepage from floods. In the sandstone areas of the west these are reliable and fairly abundant in proportion to the demands made on them. In the area of crystalline rock resources

[1] The conception of a soil catena was originally proposed by Messrs. Milne and Martin to describe certain hill-to-valley sequences in Uganda and was not intended to have any geological significance.—*Editor.*

are usually very restricted except along the line of major wadis. In these they are principally dependent on occasional floods; water is usually found only in the alluvium choking the valley, and is increasingly saline as the valley is followed downstream, because of evaporation loss, and fails entirely near the usual limit of flood. The yield of an underground source of this type is roughly proportional to the size of the catchment area upstream of the well-point and to the rainfall, but salinity and yield are affected by the shape of the rock-valley.

In the central Sudan underground supplies are often poor because of the imperviousness of the thick sheet of clay which forms the surface stratum in the plains. The isolated hills (inselberg) which protrude through the clays are often surrounded by a coarser cone of detritus which is more pervious, and local supplies are often found in pools in such hills (J. Moya) and in wells near the foot.

The basalt country of Gedaref has water in joints in the lava, but the deeper levels have no open joints and are dry. The volcanic areas of Darfur are similar.

The sandstones of the Nubian Series are a source of fairly deep water (Wad El Huri, east of Rufaa, and between En Nahud and El Fasher) and supplies are good.

The thick accumulations of unconsolidated sands, gravels, and clays in the Umm Ruwaba and Muqlad depressions carry water, but parts of these depressions (east of Tendelti) have water too saline for consumption. The marginal areas of the depressions have no water to 300 ft. depth (west of Kaka, south of Sherkeila) except close to the hills (Abbasiya), where the wadis spill out on to the outwash fan at the margin of the plain. The areas of 'qōz' frequently have small shallow supplies at the foot of the sands; distribution is dependent on the buried topography.

Water has been found in certain localities in the plain east of the Bahr el Jebel, at about 140 ft. (43 m.) depth.

In western Equatoria rivers are nearly perennial, and shallow supplies are found in river-beds (pools or shallow wells) during the short dry season. The ironstone country is similar in behaviour to the basalt country farther north, and water is found near the base of the ironstone on the plains; where ironstone caps higher ground it is dry.

In eastern Equatoria the hills have perennial small streams, but the plains are dry before the rains return. Conditions are similar to those in the northern desert area, but a higher rainfall restores shallow supplies after a brief but complete drought.

The most acute shortage of water is felt on the broad clay plains, where rainfall is good. In some localities the shortage is real because no water is found at depths which have been regarded as the economic limit (250–300 ft.).

In other localities shortage is now known to be only apparent, and water has been found when the practical limit of wells has been increased. The depressions have not yet been fully explored, nor has the area east of the White Nile and the Bahr el Jebel.

In general the Sudan is an unevenly watered region. A high proportion of the rainfall is evaporated owing to poor absorption by the soil and is

lost. Conservation measures to improve percolation are required, also to combat soil-erosion and to slow down run-off on steeper slopes.

On the plain in the region of the swamps fairly extensive drainage-works designed to introduce water into the pervious sands under the heavy clay could improve resources.

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GLOSSARY

(*Excluding rock-names of Basement Complex*, pp. 92–5)

acid: applied to igneous rocks, signifies a rock with more than 66 per cent. silica (see *basic*).

aggradation: the raising of the general level of a land surface by deposition of sediment; strictly applied to sub-aerial deposition by rivers, but loosely used to include also deposition in lakes.

arkose: a sandy sediment with noteworthy felspar, predominantly potassic (cf. *greywacke*).

basalt: a basic volcanic rock.

basic: applied to igneous rocks, signifies a rock with less than 55 per cent. of silica (see *acid*; rocks with between 55 per cent. and 61 per cent. of silica are described as intermediate).

breccia: a deposit consisting of *angular* fragments of pebble-size or larger in a consolidated condition (cf. *conglomerate*).

calcrete: a sediment cemented by calcite, generally deposited later than the sediment (see *silcrete*, *ferricrete*).

cataclastic: a fragment structure produced by rupture of crystals under stress, in a compact (recemented) rock.

chert: a non-crystalline or cryptocrystalline silica-rock, in beds, usually yellow, buff, or brown in the Sudan.

conglomerate: a deposit consisting of rounded fragments of pebble-size or larger in a consolidated condition (cf. *breccia*).

continental deposits: sediments containing very rare or no marine fossils, may contain plant-remains or remains of pulmoniferous animals.

diatom beds: deposits of a plant with siliceous test (= tripoli, diatomite).

dip: the inclination of a rock structure (bedding, foliation) to the horizontal (see *strike*).

false-bedding: inclined bedding making an angle with the major stratification-planes, caused by deposition (of sands) in rapidly moving water; = current-bedding.

ferricrete: sediment cemented by iron-oxide (cf. *calcrete*).

ferrisilcrete: sediment cemented by ferruginous non-crystalline silica (cf. *silcrete*).

foliation: parallel arrangement of crystals in a rock, produced by stress during recrystallization (metamorphism) or flow during crystallization.

granoblastic: a granular texture in metamorphic rocks, produced by metamorphism (opposite to foliated).

granoblastic-foliated: a mixed texture, matrix of quartz and felspar granular, other minerals such as mica, amphibole parallel or foliated.

gneiss: a coarsely foliated rock (cf. *schist*).

greywacke: a sedimentary rock containing a noteworthy amount of recognizable material derived from basic and intermediate volcanic rocks, especially chlorite, epidote, plagioclase (cf. *arkose*).

hamada: a stony desert, of bare rock-surfaces (see *serir*).

inselberg: an isolated steep-sided hill rising abruptly from a plain of similar rock, usually of crystalline or metamorphic rock, bee-hive or 'sugar-loaf' in outline.

insolation: diurnal range of temperature, effecting disintegration of exposed rocks.

joint: a plane of easy splitting in a rock which is not a bedding-plane; forms open fissures near the surface.

kankar: rounded nodules of calcite in clays, concretionary, also used of root-like cylinders and lenticular beds.

laterite: a deposit of more or less ferruginous clay, generally believed to be formed from any rock (including unconsolidated sediments) under special conditions of drainage and climate; lateritic deposits in the Sudan are highly ferruginous.

ortho-: prefix to schist or gneiss, indicating derivation of metamorphic rocks from an igneous rock (cf. *para-*).

para-: prefix to schist or gneiss, indicating derivation of metamorphic rock from a sedimentary rock (cf. *ortho-*).

pelite: metamorphosed argillaceous sediment.

permeable: rock or sediment through which water will pass fairly easily.

pervious: rock or sediment into which water will soak.

phonolite: an intermediate volcanic rock, similar to trachyte.

quartzite: sedimentary rock, originally sandstone, cemented by silica.

'*qōz*': sand, applied commonly to fixed dunes, generally reddened at upper surface; e.g. Kordofan sands.

rhyolite: an acid igneous rock, usually volcanic, mostly non-crystalline.

schist: a metamorphic foliated rock in which the parallel minerals, usually in flakes or needles, are close set, with a close-set fissility parallel with the foliation (cf. *gneiss*).

serir: a gravelly desert with a surface of residual or 'lag' gravels produced by the removal of finer sediment from water-deposited gravelly sediments.

silcrete: a rock cemented by non-crystalline or crystocrystalline silica (cf. *calcrete*, *ferricrete*, *ferrisilcrete*).

strike: the direction of the line of intersection of a structural plane in a rock with the horizontal plane; used of bedding, foliation or joints (cf. *dip*). The direction of strike is at right angles to the direction of dip.

tectonic movement: movement of the crust of the earth, by folding or faulting: usually on a large scale.

trachyte: an intermediate volcanic rock.

tuff: a deposit of fine-grained volcanic material, ejected from a vent by explosive activity as a volcanic ash; usually applied to water-laid or bedded volcanic ash.

watershed: the line separating two slopes draining in opposite direction (not synonymous with catchment area or basin of a river).

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INDEX OF PLACE-NAMES

	Lat. N.	*Long. E.*
'Aliab	17° 18′	33° 47′
Bayuda steppe	18°	33°
Berti hills	14° 45′	25° 45′
Butana	16°+	34½°+
Butana bridge	15° 03′	35° 59′
Chelga	12° 31′	37° 07′
Erdi plateau	18½°	23°
Garia	4° 06′	32° 51′
Gilif hills	17° 45′	32° 30′
Hudi	17° 42′	34° 17′
Imatong Mts.	4° 15′	32° 45′
Jebel Ahmed Agha	11° 00′	32° 40′
Jebel el 'Atshan	18° 09′	33° 49½′
— Auliya	15° 14′	32° 30′
— 'Eit	20° 10′	37° 07′
— Marfaibiya	17° 29½′	33° 42½′
— Marra	14° 04′	24° 21′
— Matariq	14° 25′	24° 26′
— Nakhara	18° 08′	33° 56′
— Rahib	17° 45′	27° 01′
— Rauwiyan	16° 15′	32° 37′
— Tageru	16° 00′	27° 15′
— 'Uweinat	21° 55′	25° 01′
— Zaghawi	17° 16½′	33° 42′
Kaka	10° 37′	32° 12′
Khor Arba'at	18° 53′ 19° 50′	36° 44′ 37° 15′
— el 'Atshan Sta.	13° 22′	34° 16′
— Langeb	18° 53′ 17° 17′ 18° 30′	36° 45′ 36° 40′ 38°— (sea mouth)

	Lat. N.	*Long. E.*
Khor Mog	19° 34′ 19° 37′	37° 03′ 37° 14′
Kinyeti	3° 57′	32° 54′
Laqiya	19° 53′	28° 15′
Malha	18° 06′	37° 45′
Manaqil	14° 15′	33° 00′
Meidob	15° 20′	26° 30′
Musmar	18° 13′	35° 38′
Nawa	12° 51′	30° 32′
Qōz Regeb	16° 04′	35° 34′
Rejaf	4° 45′	31° 35′
Sabaloka gorge	16° 18′	32° 40′
Sarsareib	15° 22′	35° 47½′
Sayyah	14° 19′	25° 45′
Semeih	12° 44′	30° 51′
Showak	14° 24′	35° 51′
Umm Koweika	13° 00′	32° 17′
Umm Ruwaba	12° 53′	31° 13′
Wadi Azum	13° 20′ 12° 01′	24° 10′ 32° 16′ (Mogororo)
— Howar	14° 45′ 17° 28′	22° 36′ 27° 05′
— Melik	14° 05′ 18° 03′	28° 10′ 30° 47′
— Muqaddam	15° 15′ 18° 04′	31° 15′ 31° 31′
— Seidna (mouth)	15° 50′	32° 32′
Yirol	6° 34′	30° 30′
Zeidab	17° 26′	33° 54′

The *Index Gazetteer of the Anglo-Egyptian Sudan* (1932) compiled by the Sudan Survey Department shows all place-names on maps up to 1931.

The above list includes only places not marked on the contour-sketch-map. Khors and wadis are indicated by two pairs of co-ordinates, source and mouth or point at which it ceases to be an active stream.

Co-ordinates of areas, e.g. Bayuda steppe, give roughly a central point.

The geological map (at p. 88) shows only the four main formations—the crystalline platform of Basement Complex, the Nubian Series, the late Tertiary lavas, and the unconsolidated late Tertiary to Pleistocene deposits of the depressions.

The map of the superficial deposits (at p. 112) of the area shows the distribution of the main types and is not a soil map. The region covered by ferruginous or lateritic deposits contains many small rock-masses exposed either with a modern soil cover or none. The 'qōz' area of stabilized dunes (Kordofan sands) similarly has rock-outcrops, and also patches of clay deposits on low ground. In the clay plain transported clays are widespread, locally diversified by sands representing the trace of former streams (e.g. Duk ridge east of the Bahr el Jebel). The area so shown includes recent valley deposits and rare blown sand (modern dunes). The

areas shown as 'rock under thin superficial deposits' round Gedaref, west of Sennar, in the Nuba Mountains south of Rahad, Ingessana Hills, and the Boma area have heavy clays like the transported clays of the plain. These thin superficial deposits *in situ* are heavy clays south of the arid belt. In the desert area they are residual scree or gravel with a high proportion of bare rock. In the areas so shown, soils are in equilibrium with the present natural conditions and lie on the rock from which they were formed.

Scale of Years, Geological Record

If the time from the beginning of the earliest geological record to-day were considered as equivalent to 1 year, the divisions of the calendar would appear (from 'Climate and Man', *U.S. Dept. Agric. Yearbook for 1941*, p. 70):

Kainozoic		
Quaternary	31 Dec., 6 p.m. to midnight	6 hrs.
Tertiary	18 Dec. to 6 p.m. 31 Dec.	13 days 18 hrs.
Mesozoic		
Upper Cretaceous	7–17 Dec.	15 days (Upper and Lower Cretaceous)
Lower Cretaceous	3–6 Dec.	
Jurassic	26 Nov.–2 Dec.	7 "
Triassic	19–25 Nov.	7 "
Palaeozoic		
Permian	8–18 Nov.	11 "
Upper Carboniferous	28 Oct.–7 Nov.	11 "
Lower Carboniferous	21–27 Oct.	7 "
Devonian	10–20 Oct.	11 "
Silurian	3–9 Oct.	7 "
Ordovician	18 Sept.–2 Oct.	15 "
Cambrian	23 Aug.–17 Sept.	26 "
pre-Cambrian		
Algonkian	28 Apr.–22 Aug.	234 days or 8⅔ months
Rest of pre-Cambrian	1 Jan.–27 Apr.	

Such a table is merely a rough guide to proportion; it serves to emphasize the immensity of the vista of 'geological time' on human standards of reckoning.

The Cretaceous period ended about 50 million years ago, and the Quaternary began about half a million years ago. The Palaeozoic began approximately 500 million years ago (Ball, 1939, p. 15).

Chapter VII

A NOTE ON THE ORIGINS OF THE SOILS OF THE SUDAN FROM THE POINT OF VIEW OF THE MAN IN THE FIELD

By J. D. TOTHILL, C.M.G., D.SC., B.S.A.
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'Speak to the earth, and it shall teach thee.'
OLD TESTAMENT: Job xii. 8.

Introduction

THE origin of soils has been discussed in this volume by Messrs. Andrew, Arkell, and Greene. As this is an agricultural book it may help agricultural workers to bring the information together and to add to it information obtained by Mr. Snow and the writer in the course of examining standard soil pits at representative stations in many parts of the Sudan.[1] The pits were dug in order to interpret data obtained by the analysis of samples from bored holes; to provide data for a broader understanding of the soils of the Sudan; and to give the man in the field an opportunity to see and touch and contemplate the soils and subsoils of his area.

In the course of a few years, ending in so far as this note is concerned in May 1944, standard pits were examined in substantial numbers over the alluvial lands of the Kerma basin and contiguous Wadi el Khowi, the Nuri pump-scheme, the Bouga pump-scheme, the sites proposed for a dairy farm at Atbara, the proposed pump-scheme at Aliab since developed, the Shendi pump-scheme, the lands round about Shambat, the lands of existing and prospective Government pump-schemes between Jebel Aulia and Um Garr; lines of holes were also dug across the Gash Delta and from Kosti Bridge alongside the road to Renk, Malakal and Bor with offsets Renk to Jebel Guli and Malek to Pengko. In Equatoria Province lines of holes were also examined alongside the roads from Shambe to Wau via Tonj and Meshra and from Wau to Yambio, Maridi, Yei, and Juba. A smaller series were also examined at representative sites in Darfur Province.

The standard pit adopted was 10 ft. deep, 12 ft. long, and 3 ft. wide with 1-ft. steps cut to the bottom. Samples of each foot were sent to the Soil Chemist for analysis and record, and field data were recorded in the following manner.

From the point of view of origin most of the agricultural soils of the Sudan may be conveniently discussed under the general headings riverain soils, desert deltas, the clay plain, the Nile Congo watershed, and the continental 'qōz' or sand, and in this note will be taken in this order.

[1] At the time of writing this note the author was Director of Agriculture and Forests.

SOIL INSPECTION HOLES

Date	Number of hole	Examiner	Location	Description of site	Samples	Stones	Shells	Cracks	Stratification
Day 20 Month Aug. Year 1943	Atbara Forage Farm 1	J. D. T. E. R. J. J. W. H.	100 m. NNW. of kilo 314 on railway, and 50 m. east of railway near main Nile.	Bare silt plain with a little gravel on top and a few 'tundub'* bushes	Each foot	Coarse gravel and a few big stones	No	No	Strongly marked bedded silts separated by gravel layers.

Ft. deep	Moisture	Root penetration	Colour of soil	Kind of soil†	Friability (knife test)	$CaCO_3$ nodules	Gypsum crystals	White flecks	Termites and holes	General remarks
1	No	Good	Pale grey-brown	Bedded silt	Excellent	No	No	No	No	A clear picture of finely bedded river silt with a 1-ft. bed of well-rounded river gravel with quartz in 5th ft. over more finely bedded silts over another bed of gravel. No cultivation according to the Omda for as long as he can remember, but fine roots penetrate freely through the top 4 ft. No salt concentrations.
2	,,	,,	,, ,,	,, ,,	,,	,,	,,	,,	,,	
3	,,	,,	,, ,,	,, ,,	,,	,,	,,	,,	,,	
4	,,	,,	,, ,,	,, ,,	,,	,,	,,	,,	,,	
5	,,	No	Gravel band	River gravel	Gravel is free	,,	,,	,,	,,	
6	Sl. moist	Very few	Pale grey-brown	Bedded silt	Excellent	,,	,,	,,	,,	
7	,,	None	,, ,,	,, ,,	,,	,,	,,	,,	,,	
8	Moist	,,	Gravel band	River gravel	Gravel is free	,,	,,	,,	,,	An excellent site with sweet water somewhere about ft. 10. Suitable for dura, berseem, 'lubia', dates, mangoes, and citrus.
9	Wet	..	..	..	..	..	..	..	..	
10	..	..	..	..	..	..	..	..	..	

* 'Tundub' = *Capparis decidua* Pax.

† Kinds of soil: loam, sandy loam, river silt, river sand, desert sand, sandy clay, clay sand, clay.

EXAMPLE 1. A first-class alluvial soil suitable for date culture.

SOIL INSPECTION HOLES

Date		Number of hole	Examiner	Location	Description of site	Samples	Stones	Shells	Cracks	Stratification
Day Month Year	25 Feb. 1942	Renk Offset Hole IV	J. D. T. O. W. S. J. H. S.	42·3 miles E. of Renk and White Nile	Gently rolling clay plain with light stand of red 'talh'* and some 'heglig'† and with much *Hyparrhenia* sp. at site	Each foot	Some small ones down the cracks; a quartz boulder at bottom	Dead *Limicolaria* on surface	Well developed and with slip-cracks‡	

Ft. deep	Moisture	Root penetration	Colour of soil	Kind of soil§	Friability (knife test)	$CaCO_3$ nodules	Gypsum crystals	White flecks	Termites and holes	General Remarks
1	No	Very good	Brownish	Clay	Fair	No	No	No	No	A deep strong clay somewhat tough, but with roots penetrating freely to 8 ft., with well-developed cracking system with slip-cracks and without salt concentrations. Entire absence of any evidence that soil was laid down under water. The large boulder at 10 ft. together with high percentage of quartz rubble and less clay suggest that granite rock is not far down. An excellent soil for dura.
2	”	”	”	”	Rather tough	”	”	”	”	
3	”	”	”	”	”	”	”	”	”	
4	”	”	”	”	”	”	”	”	”	
5	”	Good	”	”	”	A few	”	”	Some	
6	”	”	”	”	”	”	”	”	”	
7	”	Present	”	”	”	Appreciable	”	”	”	
8	”	”	”	”	”	”	”	”	”	
9	”	No	”	”	”	”	”	”	”	
10	”	”	Pale brown	”	”	”	”	”	”	

* Red 'talh' = *Acacia Seyal* Del. † 'Heglig' = *Balanites aegyptiaca* Del.
‡ Cracks running at an angle of some 30 degrees to the horizontal, produced by displacements and occurring in the subsoil.
§ Kinds of soil: loam, sandy loam, river silt, river sand, desert sand, sandy clay, clay sand, clay.

EXAMPLE 2. A first-class alluvial clay soil suitable for dura.

came from the Blue Nile because gypsum is common in these lands. These soils, of which Fatīsa, Hashāba, and Dueim are illustrations, vary from good to bad according to salt concentrations, and wide variations frequently occur within short distances. In places beds of river-formed limestone occur so close to the surface as to spoil these soils agriculturally.

The sand-dunes of Fatīsa and Hashāba on which melons are sometimes grown are not in origin similar to the continental 'qōz' or sand of Kordofan and Darfur but are the remains of lakeside dunes. In the mesquite plot near the top of a dune behind the Inspector's house at Hashāba is a strand line at the 382·14-metre level containing water-worn shells of *Cleopatra* and *Melanoides* representing dead adults washed up from the river or lake bed by wave action. This strand line probably marks the winter shore-line of this lake at the time of its greatest development.[1]

The scarcity of remains of the land shell *Limicolaria* in all these soils seems to indicate that these lands were still under water until about the dawn of the Dynastic period when the climate was moist enough for this large land snail to flourish at Khartoum (this is amplified in the discussion of the Gezira soil).

Kosti to Renk

The soils examined in this area are those alongside the road on the right-hand bank all close to the river. Bedding can often be made out and the soils are alluvial clays. Salt concentrations are less conspicuous than in the White Nile pump-schemes area, but gypsum crystals of the long type usually bridging the smaller cracks occur in places to within a mile of Renk. The pits produced too few semi-fossil shells to indicate whether the soils were deposited under annual flood conditions or under permanent water. The presence of gypsum, however, tapering to nothing at Renk, suggests that a good deal of the water of this reach was contributed by the Blue Nile and that the widened White Nile extended up to Renk. On the left bank the riverain soils of this reach have not been studied.

Renk to Malakal

The higher-level clay plain over which the road passes is more conveniently discussed as part of the clay plain around the Sudd. At a lower level along this part of the river recent silt, slightly reddish in colour and with a higher clay content than one normally associates with silt, is being annually deposited by the Sobat, and this provides the few areas of really good soil suitable for the production of fruit and vegetables along this part of the Nile. As these lands are flooded annually the vegetable-growing season is short. Renk marks roughly the tail of this deposit. The sand content of this soil increases as one proceeds upstream, and at Doleib Hill the tough clay of Renk has become a very nice loam.

Malakal to Bor

From Lake No to Bor is the part of the Sudd dominated by papyrus. The heavy clay soil, containing in places abundant $CaCo_3$ concretions and

[1] See Tothill, J. D., 'The Origin of the Gezira Clay Plain', *Sudan Notes and Records*, vol. xxvii, 1946.

underlain by sand, is of academic interest only and unfortunately need not be discussed. The history of the Sudd is discussed by Andrew in the chapter on geology.

The 'Toiches'

'Toich' is a Dinka name for the lower parts of the flood plains of the many rivers of the Nile Congo watershed all of which lose themselves in the edge of the Sudd. Typical 'toich' lands are those at Rumbek, Yirol,

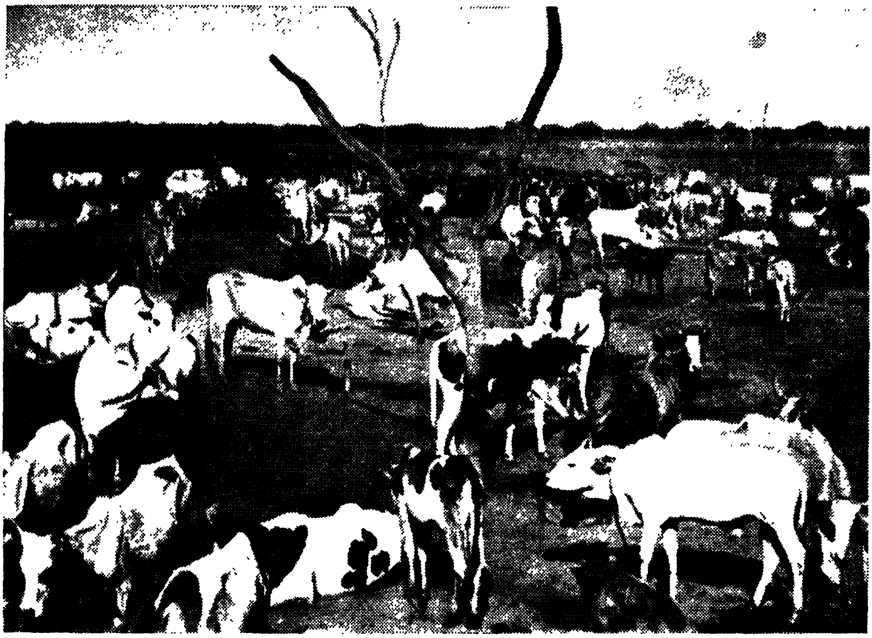

FIG. 33. A 'toich' in the Sudd marginal area. This is the plain that provides the grazing for the cattle of the Dinka, Shilluk, and Nuer tribes. Dinka cattle in foreground (*photo H. Ferguson*).

Tonj, and Wau. Bedding can often be made out showing the soils to be alluvial and poor drainage is often indicated by iron-staining. The soil of Yirol 'toich' at the point sampled by Greene (cf. Table 11, p. 170) is a stiff clay, the proportion of which varies with depth according to the strength of the current in which it was deposited; the soil, in contrast with the clays surrounding the Sudd, is somewhat acid at all levels, thus indicating the recent nature of its derivation from the basement complex catchment area; it is also devoid of visible salt concentrations. The soil of Rumbek 'toich' (Greene's Table 10 at p. 170) has been deposited in faster water as it contains only half as much clay and in this case only the upper 3 ft. are acid and therefore recent; the lower alkaline 3 ft., also river alluvium, may have been submerged by the larger Lake Sudd of the last major pluvial period, as Rumbek is considerably lower than Yirol. Some elevations kindly supplied by the Egyptian Irrigation Department are Shambe 406.5 metres, Yirol 432, Rumbek 420, Tonj 427, Wau 427,

Meshra 390 metres. The 'toich' lands join the clay surrounding the Sudd at approximately the limit of ironstone somewhere near the 418-metre contour. They are primarily used as grazing lands and apt to be too poorly drained for cultivation purposes, but the soils improve in quality as one proceeds upstream and locally according to river meander and annual variations of flood-water strength.

Bor to Juba

At Bor, the elevation of which is 422 metres, one leaves the Sudd and the vegetation changes as the river flats gradually rise to 452 metres at

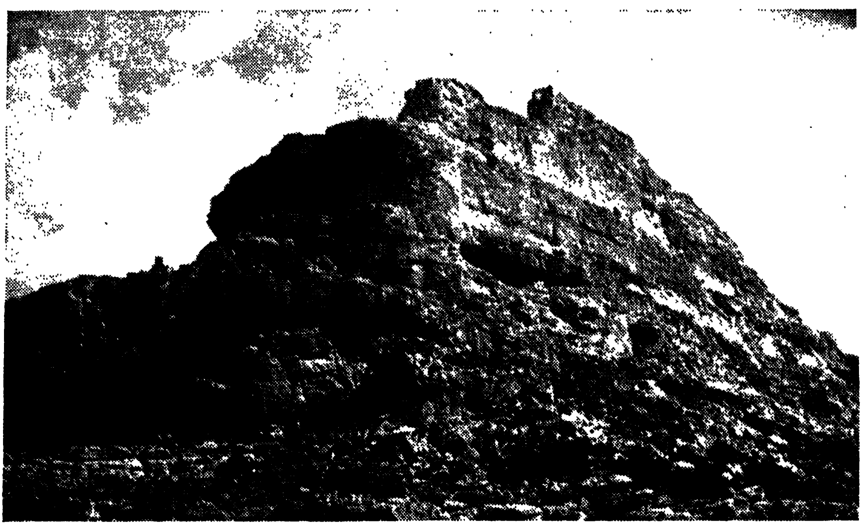

FIG. 34. The continental 'qōz' or desert sand is thought to be derived from Nubian sandstone rocks that lie to the north and north-east. This cliff 4 miles east of Abiad has a black ferricrete cap resting on alternating pink and white, almost horizontal bands of sandstone (*photo J. D. Tothill*).

Juba. At Bor the flats are only just emerging and are still covered mostly with papyrus. The soil of the banana garden on the left bank at Bor is, however, recent alluvium, representing the somewhat clayey tail of the Kit and Kaia river deltas. As one proceeds upstream these alluvial soils improve both as they become higher and drier and as the sand content increases with the approach of the head of the delta just upstream of Juba. Between Terakeka and Juba there are substantial areas of almost perfect agricultural soil consisting of bedded silts with a potable water-table from 1 to 4 ft. below the surface. These are ideal conditions for crops such as dura, cotton, sugar-cane, and oil palms, as despite the somewhat dry climate no irrigation is required. Juba itself is too close from an agricultural point of view to the head of the delta, and the river lands here are subject to flood. The potentially cultivable land may be said therefore to commence about 5 miles down-stream of Juba. As the area is a flood plain, the soil of which has been built up by a meandering river, the distribution of first-class land may be presumed to be erratic and is likely

to consist of long and narrow strips running parallel with the present channel.

Riverain Soils of Darfur Province

In the main the 'qōz' lands supply most of the food of animals and human beings in Darfur, but in special areas, particularly around Jebel Marra, recent river silts are important. These are derived in the main from the layer of soft volcanic dust erupted from the smaller steep-sided crater in the final period of activity of Jebel Marra. The dust half filled the main crater and formed a soft rock several hundred feet thick that originally covered much of the Jebel. This soft rock is now being dissected into bad lands and is being re-deposited as excellent soil to form the 'harāz' (*Acacia albida*) lands of Zalingei, the citrus lands of Suni, and the tobacco lands of Shingal Tubai.

These recent river silts overlie alluvial deposits of cracking clay that are a noteworthy feature of the rivers of Darfur illustrated by the Wadi Azum and the Wadi Ku. These are strong cracking clays, but are of no practical importance because the rainfall is insufficient for agricultural purposes and no irrigation water is available.

Desert Deltas

The Gash and Tokar

These two important agricultural areas are what may be called desert deltas. The soil consists of a recent deposit still being formed of coarse sand, finer sand, sandy loam, clay loam, and clay as one proceeds from the head of the delta to the edge of the deltaic fan.

In the case of the Gash the delta of silts is being laid down on an older bed of cracking clay that has not yet been dated but which possibly is the same age as the Gezira clay. Where crops are best the silt occurs in great depth. The underlying clay prevents the waters of the Gash flood from escaping and holds them up in an underground reservoir from which the crops drink long after the light rains have stopped. The clay foundation also makes it possible to create underground reservoirs to supply well water for the villages of the area.

What lies underneath the Tokar silt is not known.

The Clay Plain

The clay plain of the Sudan extends from the Butana to the Blue Nile, takes the Gezira in its stride, extends up both sides of the White Nile to Renk and Malakal and Bor, swings out in Equatoria Province in a great semicircle between the ironstone belt and the Sudd, and has outliers in southern Kordofan and Darfur. In all these areas the soil is a heavy cracking clay, but the origin is quite different in the Gezira, the Sudd marginal area, and the more steeply sloping plains, and will be discussed under these three heads.

The Gezira

The clay of the Gezira,[1] unlike that of the contiguous White Nile pump-schemes, is remarkably even in quality, containing rather more sand as one proceeds towards the dunes of Hashāba. There is now a good deal of evidence to indicate that the Gezira is an alluvial plain laid down by the Blue Nile and that it dried out annually during the period of deposition. A. J. Arkell has shown its age to be post-Kenya Fauresmith because at Singa this massive bed of clay rests upon a river-gravel deposit containing a bushman type of skull and artefacts of a culture that he identifies as being somewhat similar to the Kenya Fauresmith which is believed to have flourished in Kenya in the dry interval before the last major or Gamblian wet period. During its formation the Gezira seems to have dried out annually because the upper 6 ft., which have been sampled in detail, contains evenly distributed in both depth and over the whole area many semi-fossil shell remains of *Ampullaria* and *Lanistes* that breathe by both lungs and gills and that are habitually amphibious, inhabiting to-day low parts of clay plains and 'fula' in the Acacia Tall Grass Zone normally covered with rain or gently flowing flood-waters for several months of the year. The Gezira was not a lake because Andrew and Arkell have provided evidence to show that the Sabaloka gorge at this time was much as it is to-day, and that therefore there was no barrier for impounding a lake; there is also a remarkable absence of semi-fossil shells of lake-inhabiting molluscs such as the little basket shell *Corbicula*, the river clams *Unionidae*, and the inch-long, steeply spiral, rather rough *Melanoides*. The plain seems to have been inundated for 5 months or so each year because a strip along the Blue Nile in places 25 kilometres wide contains the remains of the dainty little winkle-like shell *Cleopatra* occurring in all age groups. This species breathes by gills only and is able to travel in water fairly rapidly. The sunt forest floor at the Mogren, Khartoum, is annually strewn with quantities of shells of *Cleopatra* of all ages killed off suddenly as the waters recede, and this suggests that the Blue Nile annually overflowed its banks by somewhat gentle flow of the upper layer of water, that this contained the eggs of *Cleopatra*, and that the water was annually deep enough in this 25-kilometre strip to enable the species to multiply as it now does in the sunt forest. The Soil Chemists have added to the story the important point that the Gezira soil differs from the White Nile clay soils in containing gypsum, which although characteristic of waters generally, is deposited only in the presence of sodium carbonate which is abundant in the headwater country of the Blue Nile in Abyssinia.

When the Gezira plain was built up to its present level, the climate by analogy with Kenya and Uganda, possibly became drier even than it is to-day, but there is insufficient evidence as yet either to support or disprove this notion. A. J. Arkell has shown, however, that the snail *Limicolaria flammata* was abundant at what is now Khartoum at some date between 5000 B.C. and 3000 B.C. when a village of that period flourished

[1] Cf. Tothill, J. D., 'The Origin of the Gezira Clay Plain', *Sudan Notes and Records*, vol. xxvii, 1946.

on the plot of land just east of the Khartoum civil hospital, so that although there may have been a dry period after completion of the plain, perhaps represented by the salty layer of the Gezira soil, there was subsequently a period that was a good deal wetter than now close to the beginning of Egyptian historical times. At this period this land snail, now so common over the clay plain of the Acacia Tall Grass Zone in areas not subject to annual flooding, occurred all over the Gezira. This moist period of roughly predynastic late Neolithic times possibly corresponds to the Makalian wet period of Kenya and Uganda. The adult semi-fossil shells of *Limicolaria* obtained by A. J. Arkell at his Hospital site excavation are notably smaller than is normal to-day for Suki to Gedaref specimens, which suggests that the climate was changing to the present one in which this conspicuous cone-shaped land mollusc is uncommon north of Singa and unknown except as a semi-fossil north of Wad Medani.

The Sudd Marginal Area

This part of the clay plain is distinguished from the Gezira by its more gentle slope—indeed it is almost without slope—by the absence of gypsum crystals, and by the fact that it carries particularly in low situations vast populations of three amphibious molluscs adapted for life in ponds that dry out by being equipped with gills, lungs, and a close-fitting door or operculum. These snails are the right-handed apple-sized *Ampullaria*, the left-handed golf-ball sized *Lanistes*, and the left-handed conical *Pila ovata*. It extends on the right bank of the Nile from Jebel Ahmed Agha nearly to Bor and in places extends out 30 miles east of the river; on the left bank it extends between the river and Kordofan Hills from Jebel Ahmed Agha to Tonga, and in Equatoria Province occupies a semi-circular band from Wau to Shambe between the ironstone and the Sudd. This is the plain that provides the grazing and arable lands for the Shilluk, the Dinka, and the Nuer tribes.

The soil of this area may have been deposited in an area of impeded drainage of which the existing Sudd is a remnant. The soil pits produced too few fossil shells to indicate the manner of deposition, but many of them show signs of bedding. On both sides of the river are many long low banks of river sand suggesting erstwhile margins of the lake. The gentleness of slope also suggests this origin and is indicated by the following readings: Renk 382 m., Malakal and Lake No 385 m., Meshra 390 m., Shambe 406·5 m., Rumbek 420 m., and Bor 422 m. There is as yet no proof of origin of this deposit, but on *a priori* grounds it is legitimate to suspect that it is mostly Sobat river mud with smaller contributions from the many streams of the Nile Congo and Nile Chad watersheds rejuvenated in the final major wet phase of Pleistocene times.

Such a mode of origin gives rise to several agricultural difficulties. The fineness of the clay particles makes the soil very impervious to water; the lack of slope makes surface drainage difficult to arrange; and the depth of the deposit makes it normally impossible except near the edges of the old lake or where beds of river sand exist to obtain drinking-water for man and his domestic animals by sinking wells.

The More Steeply Sloping Plains

In many parts of the Sudan, lying between the Gezira or the Sudd marginal areas already described and the hills, are extensive areas of cracking clay derived from the decomposition of rocks *in situ*. Examples are the plains of the Butana, of Gedaref and Gala en Nahl, of Sennar to Kosti, of Renk to Guli and onwards through the lower parts of the Fung, of Pengko east of Malek, and of parts of southern Darfur.

These clay plain soils differ from those already discussed in being much more pervious to water and by reason of the steeper slopes in being better

FIG. 35. 20 ft. of recent bedded silts overlying 5 ft. of clay in the Wadi Sarafaya about 30 miles NW. of Fasher. These silts make excellent agricultural soils where water is available (*photo J. D. Tothill*).

drained; the surface where rainfall is sufficient typically carries a fairly dense population of the air-breathing snail *Limicolaria flammata* Caill. with a 3-inch long cone-shaped shell and does not support except in odd pockets the amphibious molluscs of the Sudd margins. Soil pits show no bedding, but there is frequently a top layer of recently transported material, containing more sand, the depth of which varies with slope and distance from the source. Salt concentrations are typically absent.

The cracking-clay soils of these more steeply sloping plains provide some of the best soils in the Sudan for the production of rain-grown dura, particularly in the Blue Nile and Kassala Provinces. The provision of drinking-water is often difficult, but there are in many places good prospects of obtaining water by boring into the underlying rock.

The Nile Congo Watershed

The agricultural soils of this area have been discussed as to origin by Greene and Andrew and little need be added. They occur as reddish clays and clay loams in Yei, Maridi, and Yambio in well-drained situations

often on a considerable slope. Many of the pits showed remains in various stages of decomposition of the basement complex micaceous rock from which the soil had been derived. In a number of instances a surface layer of transported material containing sand and gravel occurs varying in thickness according to the slope and distance from source of the eroded sediment. There is no bedding, and roots penetrate freely in the best of these soils to great depth.

Some of the pits showed that the soil had disappeared by sheet erosion caused by cultivation and that the subsoil was now on the surface, thus showing that great care will be needed in working these soils.

FIG. 36. Continental 'qōz' or desert sand with alluvial cracking clay plain in foreground. Sixteen miles from Gineina on Wadi Kaja. The clay represents the highest river terrace. The sharp contact between 'qōz' and clay is characteristic (*photo J. D. Tothill*).

As one proceeds away from the watershed on to flatter land there is often a layer of soft laterite under the soil typically with a good many termite runways. Farther north again the soil has disappeared and is replaced by laterite, which is exposed and hardened into the ironstone plateau discussed in detail by Andrew (p. 102). This relic of mid-Tertiary times has since been dissected, and soils of the valleys show a higher proportion of transported materials, including pea iron gravel, than do those nearer the watershed.

A feature of these red soils due to their origin is that they are strongly acid and suitable therefore for tea production but not for Arabian coffee.

The Continental 'Qōz'

The main agricultural soil of Darfur and of northern Kordofan is the vast area of billowy sand that absorbs all rain that falls and that stores it until exhausted by growing plants. It is thought by Edmonds to be probably older than the clays, but no conclusive geological or archaeological

proof of age has yet been obtained. It appears to represent a breaking down of Nubian sandstone rocks (cf. Fig. 34) that lie everywhere to the north and north-east of the 'qōz' into a desert sand that advanced southward in one or more of the dry periods suspected to have occurred in the Sudan in Glacial times but not yet dated.

Naturally with such an origin the 'qōz' is not a rich soil, but it produces good crops of bulrush millet, *Pennisetum typhoides* (Burm.) Stapf and Hubbard, which is the staple food of the area, and of melons.

FIG. 37. A cracking clay lake bottom in 'qōz' country 10–13 miles east of Fasher. This is now a temporary shallow lake supporting *Ampullaria* and *Physa*. In the last wet period of Pleistocene times the lake was deeper, as fragments of *Ampullaria* shells occur up to the 20-ft. level on the 'qōz' (*photo J. D. Tothill*).

CONCLUDING REMARKS

The agricultural soils of the Sudan vary greatly according to the manner in which they have been formed. The vast majority consist of re-deposits with an important residue of soils formed *in situ* from weathering of the underlying rock covered with a thin or thick layer of recently eroded material.

In order of age the recent or low level silts are the youngest; these are still being formed and probably date from the beginning of the Egyptian Dynastic period. The Gash and Tokar and Kit river deltas are of similar age. Equally young are the basin clays still being formed between Roseires and Kerma. All these presumably march with the present climate.

Next in order comes the alluvial clay that underlies the Gash silt, the alluvial clay of the Gezira, the alluvial lake-bottom clay of the White Nile pump-schemes, and the lake-bottom clay of the Sudd margins. The age of these clays is not necessarily identical and remains to be proved over large areas. The best dating so far is Arkell's determination of the layer just beneath the Gezira clay at and near Singa as being close to Kenya

Fauresmith on the basis of artefacts found in that layer. This dates the Gezira clay as probably Gamblian, this representing the final major wet period of Glacial times.[1]

The Continental 'qōz' is regarded by Edmonds as older than the clay plain, but it has not as yet been precisely dated. It seems to be older than the White Nile because at Kosti it occurs over a considerable area on the right bank.

The oldest soils are the non-alluvial cracking clays of Gedaref, Gala en Nahl, Jebel Dud, Jebel Guli, and the red acid, also non-alluvial, soils of the Nile Congo and Nile Chad watersheds formed from the weathering of the ancient underlying rocks.

[1] There is some doubt as to whether great redeposition of soil has taken place in pluvial periods or at the beginning of the succeeding dry periods. In Fiji, which is the wettest place known to the writer and where rank vegetation of either broad-leaved forest or reed firmly binds the soils, there is remarkably little active redeposition of gravels, sands, and silts, but there is active deposition of clay in the mouth of the Rewa river. It may be that clays are characteristic of pluvial periods and sands, silts, and basin clays of the post-pluvial dry periods when vegetation has lost its grip.

Chapter VIII

SOILS OF THE ANGLO-EGYPTIAN SUDAN

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1. Factors which determine the Best Use for Land

THE physical features of a country, its geological features, and its climate work together to produce like a patchwork quilt the various kinds of soil which are their necessary outcome. The physical features of a country, its geological features, and its climate cause its inhabitants to settle in certain areas and to follow certain trades. In a general way the same is true of the distribution of plants and animals. It is accordingly a matter of absorbing interest and of some practical importance to study the delicate but compelling ties which relate the geographical distribution of soils, plants, animals, and men. An experienced observer might with some confidence infer of one sample of soil that it came from a cold, sparsely inhabited country with coniferous vegetation; of another that it was taken from a densely populated, closely cultivated, tropical valley subject to seasonal flood; and might recognize a third as being taken from a hill-side vineyard beside the Mediterranean. He would feel certain that no one could grow grapes on the first soil, conifers on the second, or rice on the third.

The practical problem usually takes the form: what is the best use for this land? Whether the area under consideration be a few acres or thousands of miles in extent, this question should be answered by drawing upon all the available information. In many cases a correct decision can be reached with very little trouble by noting first those factors which clearly have an overwhelming influence. In the Sudan, for example, water is short and communications are bad. Distance from river and rail is therefore a more useful guide to possibilities of agricultural development than, let us say, a determination of clay content or nitrogen. On the other hand, if conditions are generally favourable careful examination of the soil may be of great value. The subject of land utilization has been ably discussed by C. E. Kellogg and J. K. Ableiter writing in the United States (9). They urge that land classification should be based on strict technical principles and that the survey should be sufficiently detailed to be directly applicable to holdings of normal size. By normal size is meant normal for a region in which some use such as cropping, grazing, forestry, or recreation is made appropriate by its special features of climate, soil, topography, and accessibility to markets. These physical features affect or determine the size of the individual holding, the general agricultural character of the region, and the system of land tenure which is best suited to it.

In the main, climate, soil, and the topographical features which direct human destiny remain for long periods almost without change, and if they are studied and placed on record it is to enable us to adapt our lives to these conditions. To a less degree it has been possible to alter our environ-

ment. The building of a railway, the construction of a dam, the installation of a drainage system, and the application of fertilizers may be looked upon as changes imposed on the topography, climate, and geology of a region. Because these conditions are changed new levels of agricultural development are reached. There usually ensues an appreciable change in the soil and in the plant and animal life of the district. It is now widely known that misuse of land can lead to the damaging changes in soil and water-supplies which are associated with soil erosion.

In these general remarks soils have been presented in the guise of variously coloured patches on a map, that is, as areas. Two other dimensions are needed. Firstly, soils have depth and consist of a number of layers called soil horizons which together form a characteristic sequence called a soil profile. These features may be lacking, however, in a recent deposit and the soil is then said to be immature. The variations with depth are frequently distinguishable by eye, but in many cases chemical or physical tests are found more useful. Any detailed examination of soil necessitates digging a pit or using a boring-tool; inspection of the soil surface is not enough. Secondly, soils should be considered in relation to time. A soil is not the same in summer and in winter nor before and after yielding a crop. These seasonal changes also are sometimes to be seen at a glance and sometimes are more conveniently followed by laboratory tests. The name 'soil rhythm' has been proposed for these changes in the soil with time. These changes will not be discussed here in any detail, but they are of importance to the farmer and it should be noted that soil is not simply an assemblage of inert mineral particles but is an organized structure. It has some resemblance to a living organism, but may also be compared to a clock. If one were considering buying a clock one might ask (1) Is this clock really needed? (2) Is it well made? (3) Is it wound up? (4) Does it show the right time? The practical questions one should ask about soil are rather similar. In the first place, has the soil good access to markets? If not, it will hardly merit detailed study. If it has good access to markets its fertility should be estimated by suitable tests. It should further be considered whether the soil is situated so as to receive enough but not too much water and whether it is being cropped in a reasonable rotation.

2. Soil Regions of the Sudan

Let us now begin a brief survey of Sudan soils from this point of view. The first fact to note is that the Sudan is a hot, dry country. In consequence it contains no soils resembling those of cold or temperate countries. Agricultural methods worked out in temperate countries are therefore in some cases quite unsuited to Sudan soils.

2 (*a*) *The Northern Desert*

The northern half of the Sudan is desert. To the west the land is flat; to the east bare rocky hills are being worn down to a featureless and lifeless plain. The hot days and cool nights lead to the fracture of granitic rock; the softer Nubian sandstone is fretted by wind-blown sand. This area is traversed by the Nile, beside which are small irrigated plots producing

dates and grain, citrus fruits and legumes. These alluvial soils are very patchy. A fertile deposit of silt or clay may adjoin others more or less impregnated with salts formed by evaporation of river water. Transport is costly because cataracts hinder navigation on the Nile. The railway system completes the route between Khartoum and Cairo and also gives access to the Red Sea. Trains are liable to delay during the rains because showers, though rare, may be heavy and run-off is unchecked by vegetation.

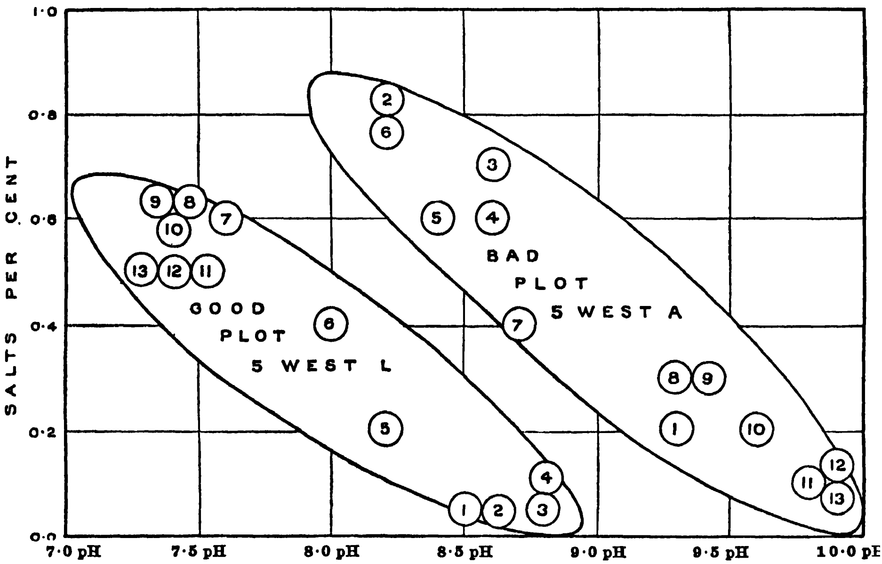


FIG. 38. Diagram showing the alkalinity and salt-content for each six-inch step down to the 6 ft. 6 in. level in the good and bad plots at Dueim of tables 4 and 5. At step 6, for instance, the 3-ft. level in the good plot has a pH value of 8·0 and a salt-content of 0·4 per cent.

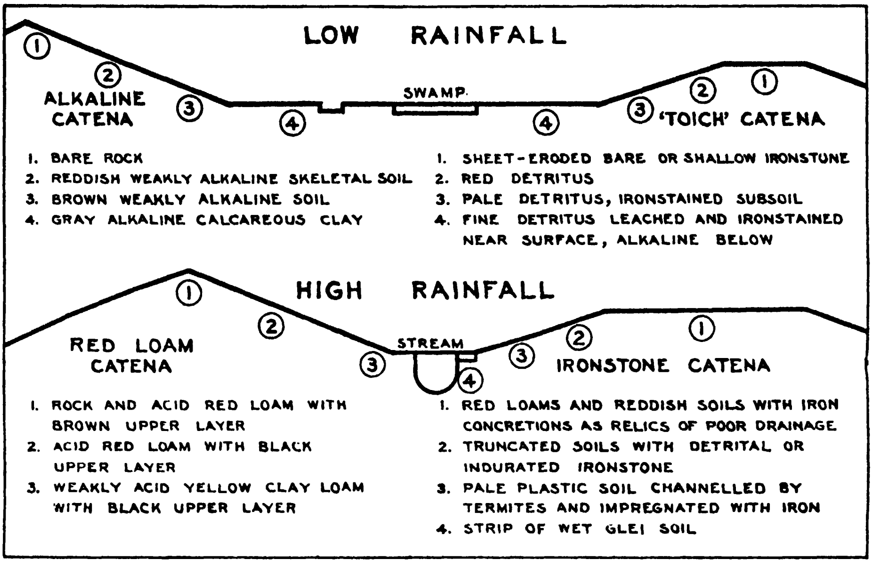
2 (*b*) *Arid Grazing Land Cultivable by Conserved Water*

South of this almost useless expanse there is a strip of land receiving summer rainfall which varies from year to year but on the average lies between 200 and 400 mm. This fringe of the rainbelt is tapped by the railway running from El Obeid to Kassala. Its natural vegetation is short grass and sparse thorn scrub which provide a period of good grazing for sheep, goats, cattle, donkeys, and camels. The local inhabitants are accustomed to raise quickly maturing grain crops by directing rain-water to selected areas. In the eastern Gezira long staple cotton is grown by irrigation from the Sennar Dam and in the alluvial fans of the Gash and Baraka rivers which permit flood irrigation during their July–August spate.[1] Grain and cotton are grown on clay soils usually brown or grey near the surface, more or less alkaline and calcareous, sometimes with a considerable content of sulphates, always of low nitrogen content. On lighter soils groundnuts may be grown; the inconspicuous gum-producing *Acacia senegal* maintains itself on inland dunes of red sand derived from the Nubian desert.

[1] An account of the Gezira soil is given in Chapter XX, commencing at p. 442.—*Editor.*

2 (*c*) *Semi-arid Belt of Tall Grass plus Acacia Woodland cultivable by Rain*

Farther south again a belt of land about 900 miles from east to west and about 200 miles from north to south receives summer rain from 400 to 800 mm. a year, the winter months being rainless. The western part is traversed by Nigerian pilgrims on their way to or from Mecca and by cattle-owning Arabs moving north and south with their horses and camels to seek new pastures. In step with the cattle move the wild game preyed



SOILS OF EQUATORIA PROVINCE 1940 PROVISIONAL CLASSIFICATION

FIG. 39. Provisional classification of soils of Equatoria Province.

upon by blood-sucking insects and lions. This district has neither rail nor river transport and its soils have not been examined. Towards the centre are the Nuba Mountains, a group of hills formerly terraced by black pagan tribes. Now that slave raids have stopped they prefer the easier cultivation of the plain. In spite of grass fires, trees survive on the hill-sides and form light woodland on the coarse reddish detrital soil below. Protection of this natural vegetation would improve water-supplies at present defective. Between the hills is a flat plain consisting of a deep clay deposit somewhat alkaline but salt-free. It carries tall grass and thorn trees and is impassable during the rains except to bulls which the natives ride. Slightly elevated areas are brown and have good tilth and are cleared for grain; in depressions the soil is grey and more tenacious and is used for short staple cotton. Further development is possible as this district lies in an angle between the railway and the White Nile. The eastern part of this belt, like the western, is occupied by cattle-owning nomad Arabs, but has the advantage of being served by the railway. The soil is mostly a brown, deep, moderately alkaline, salt-free, fertile, calcareous clay carrying tall grasses and thorn woodland including the red-stemmed *Acacia Seyal* Del from which a gum of inferior value is collected. On cleared and weeded land excellent

crops of grain and of sesame are grown, but the district still suffers from lack of drinking-water. This area abuts on the Abyssinian highland from which flood-waters sweep down the Blue Nile, Dinder, Rahad, and Atbara

FIG. 40. The 'toich' catena. Under less humid conditions the ironstone country has been subject to sheet erosion and the ironstone layer has been exposed and hardened. The pit was dug to obtain iron concretions or 'murram' for road metal. The soil column shows conspicuous cavities. 5° 38′ N., 31° 04′ E. (*photo H. Greene*).

FIG. 41. The 'toich' catena. A fertile foot slope of dark red, acid soil below a flat-topped hill capped with ironstone. The late Dr. J. G. Myers standing at left. Taken near Mboro at 7° 43′ N., 27° 43′ E., alt. 1,700 ft. (*photo H. Greene*).

rivers. With the exception of a short reach on the Blue Nile these rivers are not navigable throughout the year.

2 (*d*) *The Flood Plain and Sheet-eroded Uplands West of the White Nile*

Still farther south is the country of the Nilotic tribes, Shilluk, Dinka, Nuer, and many others. They inhabit a roughly triangular area of about

150,000 square miles bisected by the White Nile which is the main channel of communication between Khartoum and the south. Behind a barrier of papyrus swamp the western half includes a wide flood plain south of

FIG. 42. The 'toich' catena. A less-elevated situation in which the detritus is notably pale in colour. The subsoil of these lower and less fertile areas usually shows orange or black patches of iron or manganese oxides (*photo H. Greene*).

FIG. 43. 'Toich' catena. Example of low-level flood plain in this catena forming a typical 'toich'. These areas are flooded each year too long to permit tree growth but not long enough to permit of true swamp conditions developing. They form good grazing-grounds for Dinka cattle. The clay soil is typically weakly acid on top and weakly alkaline below (*photo H. Greene*).

which the land rises gently towards a plateau now cut into flat-topped hills by perennial streams. Iron concretions are conspicuous on the higher land and are thought to be relics of a period of less free drainage. Although the low land is flooded during the summer this district is, on the whole, deficient in rainfall and sheet erosion is active. The area has been visited by C. G. T. Morison of Oxford, who divides it by soil and vegetation into

four zones: (i) the red cultivated soil of the plateau, (ii) the fertile upper slope of red soil, (iii) the less fertile lower slope of bleached soil, (iv) the

FIG. 44. 'Toich' catena. The burned-off flood plain of the Mekak river at 7° 06′ N., 29° 06′ E., alt. 1,600 ft. Sampled to 4 ft. the soil was a light grey acid clay with iron mottling in the second foot and below (*photo H. Greene*).

FIG. 45. 'Toich' catena. Rumbek 'toich' which is a featureless seasonal swamp. The top foot is here weakly acid, the third foot weakly alkaline (pH 8·3) with some large calcareous concretions. The soil is mainly pale bluish-grey with iron stain in the upper zone. 6° 51′ N., 29° 48′ E., alt. 1,600 ft. (*photo H. Greene*).

flood plain showing iron-stain near the surface but sometimes alkaline and calcareous below. This group of soils has been called the 'TOICH' CATENA.[1]

[1] A group of soils is called a catena when the soils of a district are so related to topography that one kind of soil is found on the hills, a second on the slopes, and a third or fourth in the valleys. This succession may be exhibited within a few hundred feet and be encountered again and again in the course of a cross-country journey or it may extend much farther, the lowest member being perhaps a hundred miles distant from the highest one. See Milne (10). See also the footnotes on pp. 122 and 160.

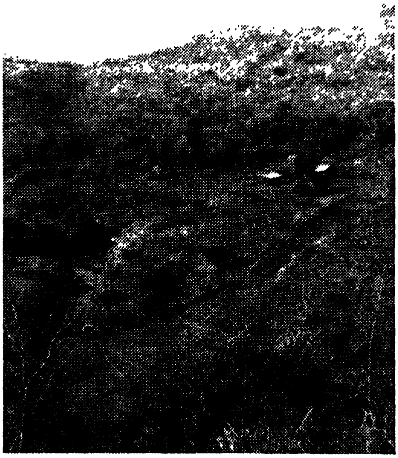


FIG. 46. An example of the highest part of the alkaline catena. The soil consists of partly weathered mountain rock. The Didinga Hills at 4° 20′ N., 32° 54′ E., alt. 3,500 ft. (*photo H. Greene*).

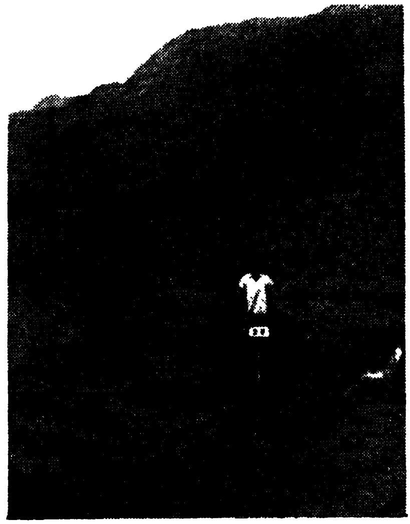


FIG. 47. The upper part of the alkaline catena at 4° 30′ N., 32° 54′ E. The pit was dug in a reddish, weakly alkaline grit. Note the thin crop of dura and the typical drought-resistant vegetation of the hills, alt. 2,000 ft. (*photo H. Greene*).

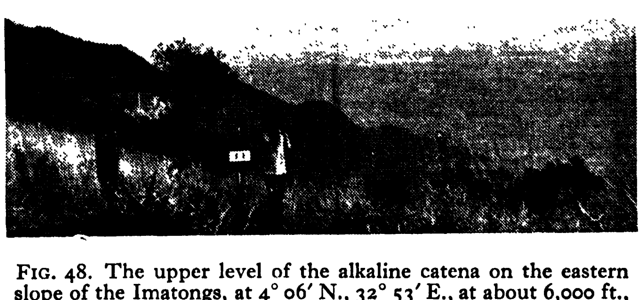


FIG. 48. The upper level of the alkaline catena on the eastern slope of the Imatongs, at 4° 06′ N., 32° 53′ E., at about 6,000 ft., looking toward the Lafit Mts. A shallow, stony soil supporting a drought-resisting vegetation (*photo H. Greene*).

Photographs Illustrating the Alkaline Catena

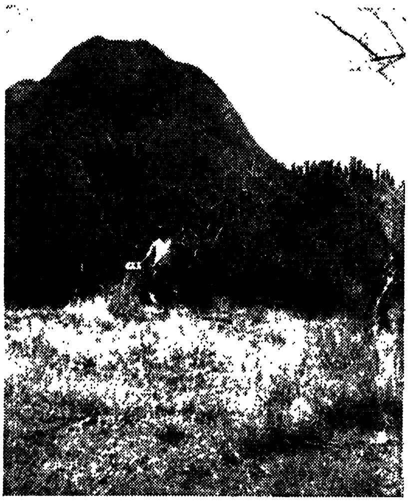


Fig. 49. The alkaline catena. A strip of coarse, reddish soil below the hill and fringing the wide-flat valley of the Kidepo river, at 4° 10′ N., 33° 15′ E., alt. about 2,000 ft. Note the drought-resisting, thin grass, *Sanseveria* and *Euphorbia*. (*photo H. Greene*).

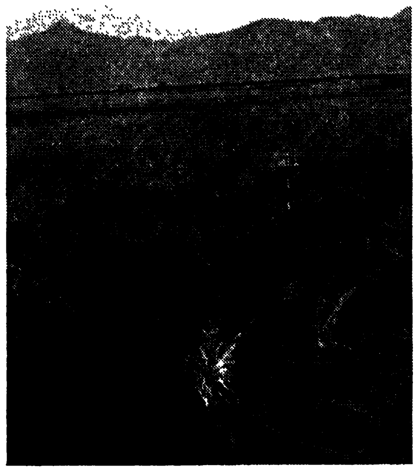


Fig. 50. The lowest-lying member of the alkaline catena. Looking west across the Kidepo valley, the line of trees marking the dry river-bed. The soil is a grey alkaline clay. 4° 19′ N., 33° 15′ E., alt. about 2,200 ft. (*photo H. Greene*).

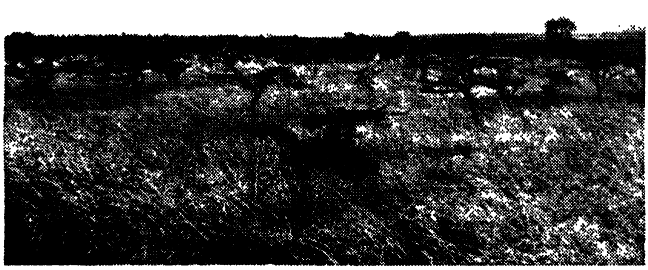


Fig. 51. Another example of the lowest member of the alkaline catena where the soil is an alkaline grey-brown clay consisting of fine material carried northward from the Didinga hills. 4° 40′ N., 33° 38′ E., alt. about 2,300 ft. (*photo H. Greene*).

The first three soils are non-plastic, the fourth shows variation in this respect: the vegetation ranges from the potentially dense forest of the plateau through light woodland including *Anogeissus* and *Combretum* to the tall grasses of the almost treeless plain. In the wet season great herds of long-horned cattle migrate to the higher land. A few months later thirsty bees make this untenable and the cattle return to their pastures on the plain.

2 (*e*) *Semi-arid Grass Plains East and West of the White Nile*

East of the White Nile with its fringe of papyrus swamp there is a trackless expanse of heavy clay hidden by tall grass and inhabited by elephant, buffalo, giraffe, and other game. Flooded during the rains, this plain is almost waterless during the dry season. This is the lowest member of a group of soils which occurs in hot predominantly arid climates. This group has been called the ALKALINE CATENA and is met, for example, in the Nuba Mountains district. Its highest member is the partly weathered mountain rock on which a scanty, drought-resisting vegetation finds a foothold. Below this is the coarse reddish weakly alkaline detritus carrying hardy thorn bushes and spiny succulents. Below this again is a fertile brown soil, moderately heavy and sometimes containing a few stones, salt-free, weakly alkaline and calcareous, low in nitrogen content. This passes into the more strongly alkaline, grey, plastic, siliceous and calcareous clay, free from stones, very sticky in the wet season, deeply cracked when dry, and of low salt-content. It is this soil which is commonly but inappropriately called 'black cotton soil'.[1] Its normal vegetation is grass and Acacia. The area described extends from mountains near the Uganda border to the Sobat river and has no present economic value.

2 (*f*) *Humid Hilly Country to the North of the Uganda and Belgian Congo*

Near the Uganda and Belgian Congo boundaries there is a marked increase in rainfall and this leads to the formation of another group of soils, called the RED LOAM CATENA, which are characteristic of a hot, moist climate. Under the combined action of rain and plant roots elevated rock masses are deeply weathered, silica and bases being dissolved and carried away by drainage waters. There is a corresponding increase in the iron and aluminium content of the residue, these changes being best observed by analysis of the clay which consists of the finest particles of soil. A leached acid soil containing a non-plastic clay is thus developed from rock which, if powdered and shaken with water, appears faintly alkaline in reaction. The characteristic vegetation is rain forest, but tall grass is most common on land which has been cultivated. Beneath a layer of leaf litter the soil is black or brown near the surface and uniformly bright red below to a depth sometimes of metres; it is notably open in texture, moist, and permits deep growth of roots. On the other hand, its content of plant foods may be small. P. Vageler (4) has pointed out that rain forest maintains itself on a small amount of plant foods, the necessary bases and phosphate which are withdrawn by the roots being returned to the soil as litter

[1] See p. 5 for an explanation of why this expression is inappropriate.—*Editor.*

Photographs Illustrating the Red Loam and the Alkaline Catenas in Equatoria Province

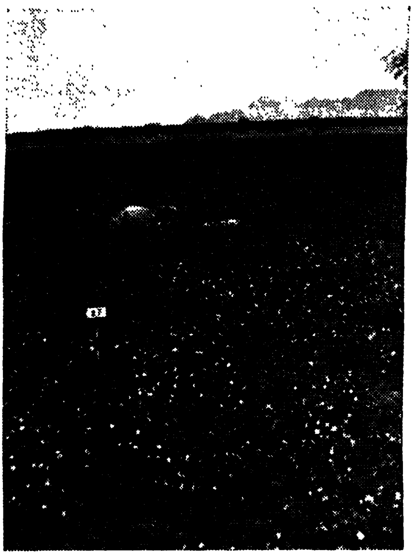


Fig. 52. Cotton growing on the lower part of the alkaline catena near Chalamni village at 4° 28′ N., 32° 52′ E., alt. about 1,900 ft. The light colour of this cracking clay is due to the large amount of white calcium carbonate in the subsoil. (*photo H. Greene*).

Fig. 53. The red loam catena. These acid soils are produced from the same rocks as the alkaline catena but under heavier rainfall. Note the bracken, fern, and *Rubus*. 4° 02′ N., 32° 50′ E., alt. 5,000 ft. (*photo H. Greene*).

Fig. 54. The red loam catena at a high level produced from basement complex rocks. *Lobelia giberroa* Hemsl. flourishes in this rainfall. Near 4° 02′ N., 32° 50′ E., alt. 6,000 ft. The soil is bright cocoa red and in good physical condition. (*photo H. Greene*).

Fig. 55. An example of red loam catena. A deep soil with pH about 5. Lotti forest in the Acholi Hills with *Coffea canephora* as an undershrub. Many species of giant trees grow in this wet, tropical forest. 4° 02′ N., 32° 33′ E., alt. 3,000 ft. (*photo H. Greene*).

FIG. 56. Red loam catena. Remains of a strip of gallery forest near Yei behind area cleared for tsetse fly control. Near the stream the soil is a weakly acid, yellow clay loam. Above this on the slopes is an acid, red loam. 3° 45′ N., 30° 38′ E., alt. 3,300 ft. (*photo H. Greene*).

FIG. 57. The ironstone catena near Yambio. This is an area of good rainfall and much used for shifting cultivation. Soils are characteristically red on the hills and pale in the valleys, and always acid (*photo H. Greene*).

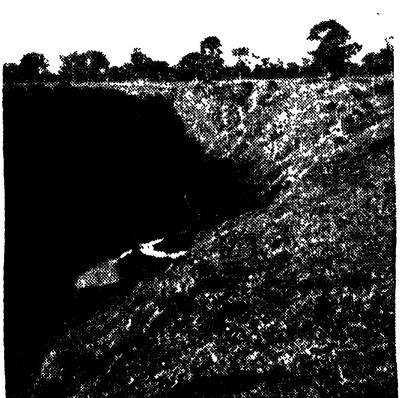


FIG. 58. The ironstone catena near Yambio showing luxuriant tree growth near a spring. Away from the spring *Acacia sieberiana* is a common tree. An acid, red soil (*photo H. Greene*).

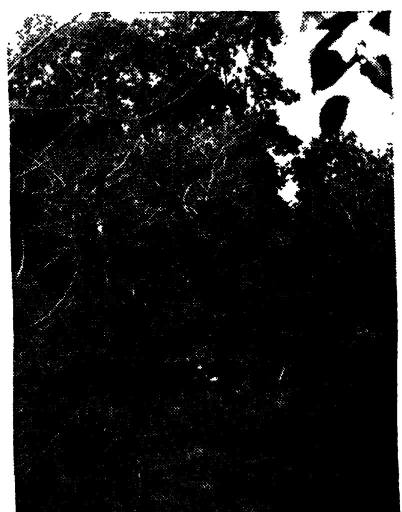


FIG. 59. Valley formation in the ironstone catena at Tambura, 5° 36′ N., 27° 28′ E., alt. 2,100 ft. The gully ends abruptly 100 yds. from the camera (*photo H. Greene*).

and used again. This is not the case when the forest is felled and the ground is used for crops of which a considerable part is taken away. Moreover, unless a good cover is maintained the soil may be ruined by loss of humus. In rather lower situations the soil is yellow, heavier, and more plastic, and the humus layer may be darker and deeper. These soils are closely cultivated as are the very similar soils of the Nile–Congo watershed. Their total extent in the Sudan is, however, small.

FIG. 60. Ironstone catena and valley formation at Tambura. Note layer of tumbled boulders of ironstone in background; a smooth ironstone field with short grass; and the steep slope with a metre of hard ironstone overlying several metres of decomposed rock with a spring at the bottom where women are filling their water-pots. 5° 36′ N., 27° 28′ E., alt. 2,100 ft. (*photo H. Greene*).

FIG. 61. A close-up of the tumbled ironstone boulders shown in the last figure. Ironstone catena, Tambura, 5° 36′ N., 27° 28′ E. (*photo H. Greene*).

2 (g) *Humid Ironstone Plateau Country along the Nile Congo Watershed*

Along the Nile Congo watershed rainfall approaches 1,200 mm. and the soil, red and non-plastic on the hills, pale, mottled with iron-stain and slightly plastic in the valleys, is closely cultivated with eleusine, cassava, sweet potato, banana, and other crops. In spite of transport difficulties some short staple cotton is exported. The grass *Imperata cylindrica* Beauv. is a common weed and prevents much soil erosion. Magnificent trees persist in some of the valleys. When the valley has a swampy margin the soil is likely to be slate colour with yellow and bluish stains and when cut has a greasy appearance. Mushroom-shaped termite mounds are found here and also on almost bare sheets of ironstone. There are few animals either wild or domestic. This group of soils has been called the IRONSTONE CATENA (cf. Fig. 66).

3. The Effect of Rain on Soil Formation

It is now clear how large a part is played in the Sudan by the summer rains. They impose a seasonal migration on men, wild and domestic animals, and even on insects; the time and method of cultivation are determined by them. In conjunction with topography they produce fairly well-marked zones of natural vegetation and of soil. This is a consequence of surface run-off and of drainage which causes high land to receive less and low land to receive more than its fair share of rain-water. The rain has a mechanical action in washing down small loose particles to form a

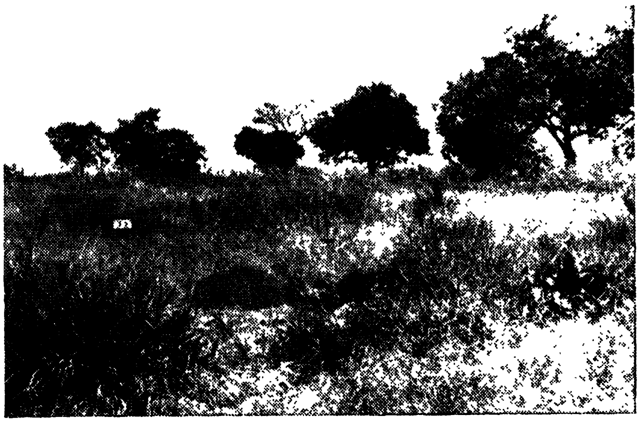


Fig. 62. Vegetation on the lower part of the ironstone catena where a plastic subsoil partly impregnated with iron shows the influence of a fluctuating water table. 3° 42′ N., 31° 41′ E., alt. 3,000 ft. (*photo H. Greene*).

plain of heavy soil from which the hills rise abruptly. In more humid regions there is vegetation to arrest this movement of soil particles and a rolling landscape may be formed. The rain also has a progressive chemical action. At first bases and silica are dissolved from rock fragments and, in a later stage not found in arid regions, the iron and aluminium of the minerals pass into solution as hydroxides. Once dissolved, the bases and silica retain no trace of character visible in the parent minerals. In humid regions these substances are carried away in the streams, but in arid regions the waters run off into the plain and evaporate there, with the result that the alkaline clay soil of the plain is enriched in bases and in silica.

4. The Structure of Soil Clay

It has long been recognized (23, 24, 25) that characteristic properties of soil are in some way localized in the finest clay particles, but whereas these were formerly called colloids and were considered to have a somewhat glue-like character, they are now thought to be semi-crystalline bodies whose surfaces and interstices retain water and bases. The two main types recognized are the Kaolinite or non-plastic type and the Montmorillonite or plastic type (28, 29, 30). In comparison with Kaolinite,

Montmorillonite contains more silica and more exchangeable bases and it has the additional property of swelling when moistened and contracting when dried. These features are found in the clay of arid countries, and one would therefore expect the Montmorillonite type to predominate in the Sudan. Although the careful researches of S. Mattson (26, 27) support a different view, there is reason to think that the bases and silica dissolved

FIG. 63. The ironstone catena. Shallow ironstone country near Amadi. C. G. T. Morison of Oxford stands before a tree the roots of which freely penetrate the ironstone layer. *Isoberlinia doka* is a common tree on such soils. (*photo H. Greene*).

FIG. 64. The ironstone catena near Maridi. A native assistant is resting his hand on what seems to have been a boulder of rock weathered in situ to ironstone, the upper surface having a hard black crust and the lower part consisting of a soft white and red ferruginous material. Surrounding the boulder are many small rounded concretions of pea iron loosely packed but in the mass forming a resistant bed. Note the pure stand of *Imperata* (*photo H. Greene*).

by rain and carried on to the clay plain are not merely mixed with the clay particles, but are combined with them to form a remarkable structure such that atoms of silicon and aluminium form layers within which basic atoms are neatly arranged. For atoms to assume a regular spatial arrangement is no uncommon matter and is illustrated, for example, by a crystal of salt, but this clay structure has two exceptional features: (1) the bases are exchangeable, (2) water can pass in and out between the silicon and aluminium layers, the distance between them being correspondingly increased or reduced. During the past 20 years base exchange has been intensively studied and is discussed in text-books and scientific journals of which some

are listed at the end of this chapter. Only a very bare outline can be given here. In the alkaline clays of the Sudan, calcium is usually the main constituent of the exchangeable bases, and the soil then usually has good tilth. This good tilth is lost and the soil becomes impermeable, strongly alkaline, and infertile if any considerable proportion of sodium takes the place of the calcium. Such an exchange occurs when river water evaporates in the presence of soil, and this is why alluvial deposits in places friable and fertile are elsewhere hard or sticky and barren.

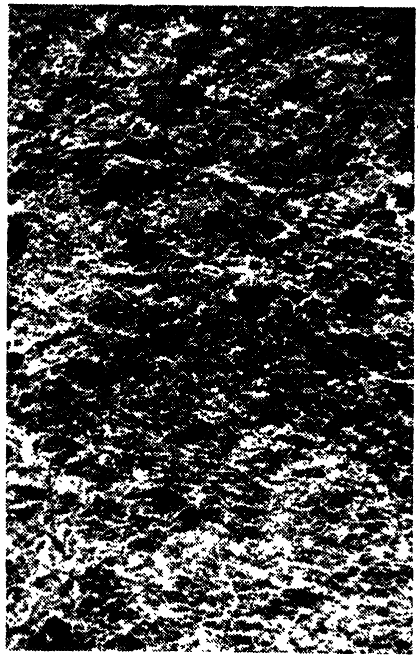


FIG. 65. The ironstone catena. A close-up view of ironstone at Tali Post, 5° 34′ N., 30° 47′ E., alt. 1,600 ft. The largest cavity is about a hand span across. Near the surface it is hard and rock-like, but 3 metres down where the photo was taken it is soft and reddish-yellow. (*photo H. Greene*).

Much scientific work has been done on the wetting and drying of soils considered both in the field and in the laboratory. In the Sudan it has been found that irrigation and bare fallow have opposed effects on the physical condition of soil. The structure of soil clay now being gradually revealed by seemingly remote academic investigations, carried out in many parts of the world, will probably be found to have a practical bearing in the Sudan also.

It seems likely that the complicated structure of clay is something which has been built up (synthesized) and is not simply a residue of decomposition. If clay is thus built up under natural soil-forming conditions it is not surprising that its properties are found to be closely related to these conditions. One important property is the readiness with which clay takes up water. Some clays take up much water and swell greatly, others do not. This is illustrated for example by the following figures selected from Tables 8–17 for soils which happen to be fairly alike in their mechanical composition. (The test employed is shaking 20 grammes of soil with a solution containing sodium carbonate; the volume of sediment is subsequently measured.)

Place	*Foot*	*Volume of Sediment*	
Chalamni	1	118	Examples of a swelling clay.
Liria	5	92	
Mboro	2	25	Examples of a non-swelling clay.
Lotti	3	28	

The swelling clays have the remarkable property of retaining traces of their history during the few months or years preceding examination. One which has been irrigated for some months or which comes from a

relatively moist situation, will swell more quickly than another which has not been irrigated for some months, or which comes from a relatively dry situation. The behaviour of the clay soils in the field resembles their behaviour in the laboratory. A clay soil which has for some months or years been dry and aerated will have a good tilth when moistened and yield a good crop; a clay soil which has been wet and lacking in aeration for some months in the recent past will, when moistened afresh, have a poor tilth and yield a poor crop.

FIG. 66. Ironstone catena. An example of bare ironstone exposed and hardened as a result of sheet erosion near Tambura. Mushroom-shaped termite nests are characteristic (*photo H. Greene*).

Now an assemblage of sand grains has no structure of the kind under discussion and does not behave in this way. It might be wet or dry, but there would be nothing to show what its previous condition had been. It seems therefore that the peculiar behaviour of the swelling clay soils is due in some way to changes in their structure, but it is not yet known precisely what those changes are. To the present writer it seems a permissible conjecture that alternate wetting and drying are pre-eminently the means whereby the clay structure is built up during the decades or centuries of soil formation, and is also the means whereby that structure is modified during such shorter periods as are associated with a few seasons of irrigation or with a temporary shift of a drainage line. The matter is one which awaits further study.

5. The Effect of Geology on Soil Formation[1]

The influence of climate and topography on Sudan soils has now been reviewed. Geological factors which are conspicuous for example in the British Isles have less effect here because the high land is mostly un-

[1] This should be read in conjunction with the section on soils in Andrew's chapter on geology. 'Catena' as used originally by Milne and W. S. Martin to describe the relationship between contiguous hill and valley soils in Uganda bears only accidental relationship to the underlying rocks. Some geologists would prefer the expression to be used more definitely in relation to the underlying rocks.—*Editor*.

cultivated and because the geological structure of the plain is hidden below a thick deposit of fine material carried for the most part by water but to some extent by the wind. A geological factor is evident, however, in the fact that soils adjoining the Blue Nile contain sulphate which distinguishes them from other alkaline clay soils. This is the case with the irrigated soils of the Gezira which, owing to their economic importance, have been closely studied. The reader seeking more detailed information about the cotton-growing soils of the Gezira and of the Gash Delta is referred to the list of publications at the end of this chapter. In the more humid region of the Southern Sudan another geological factor is evident in that soils of the 'alkaline' and 'red loam catenas' are derived from fresh mountain masses of igneous rock usually having gneissose foliation, whereas soils of the 'toich' and 'ironstone catenas' which occur west of the White Nile are formed from material which, it is thought, had been weathered in an earlier period, probably mid-Tertiary according to Andrew. The red iron concretions occur there as more or less dense beds of pellets, sometimes cemented together by later deposition of iron, forming a hard but permeable mass a metre or more in thickness. In some cases the beds are evidently detrital, in other cases the original rock structure is discernible in the ironstone. It has been suggested that in its most typical form the ironstone appears as an exposed and indurated subsoil in which are sometimes preserved the channels formerly used by termites. It seems probable that the concretions are relics of a time when the plateau was an imperfectly drained plain subject to a climate having alternate wet and dry periods. On this view the 'alkaline' and 'red loam catenas' differ from the 'toich' and 'ironstone catenas' in that the former are derived from fresh and the latter from weathered parent material. The differences arising from this source are, however, less striking than the resemblances imposed by climate and topographical situation. The relations between these four catenas are summarized in the diagram shown at Fig. 39 on p. 147.

6. Analytical Data for some Typical Alluvial Soils

Having completed this general survey of Sudan soils it is of interest to consider in more detail some examples of riverain deposits, good and bad, at El Bouga, and Ed Dueim.

El Bouga village lies on the west bank of the Nile about 40 miles north of its junction with the Atbara. Here an area about 8 miles long and about 1 mile wide is irrigated by pump. Although the higher lying land has an earlier origin, a large part of this area appears to have been deposited recently and it may be swept away no less quickly by the powerful flood-waters of the Nile and Atbara. Islands appear and disappear or move downstream and disputes about land ownership are frequent. The deposits are therefore far from stable. They are laid down as the river swings from side to side. The receding water throws down first sand which may show current bedding and then as it becomes shallower silt and clay, of which the fine lamination may be lost under cultivation. In some places deposition has been rapid and regular and the product is a good medium for plant growth, but in others a sand- or mud-bank has formed in such a way

as to permit much evaporation of river water from its damp surface with the result that calcium carbonate and sodium sulphate have been concentrated there. As further deposition occurs the sodium sulphate reacts with the fine clay particles which lose calcium in exchange for sodium and acquire very unfavourable physical properties. The calcium thus displaced may remain in the form of crystals of gypsum. The presence of calcium carbonate concretions and of gypsum is therefore a bad sign in riverain deposits.

TABLE 1. *El Bouga, G.21*

Very fertile recent deposit of yellow-grey sandy silt of low salt-content and only moderately alkaline.

Ft.	*Mechanical composition**					*Salts per cent.*	*pH†*
	Stones and gravel	*Coarse sand*	*Fine sand*	*Silt*	*Clay per cent.*		
1	0	0	61	9	31	0·03	8·3
2	0	0	42	20	38	0·04	8·4
3	0	0	60	15	25	0·03	8·4
4	0	0	73	9	17	0·04	8·5
5	0	0	69	10	21	0·08	8·5
6	0	0	74	9	17	0·04	9·2

TABLE 2. *El Bouga, T.15*

Less fertile, salty, alkaline grey clay, hard when dry, very sticky when wet, contains $CaCO_3$ concretions.

Ft.	*Mechanical composition**					*Salts per cent.*	*pH†*
	Stones and gravel	*Coarse sand*	*Fine sand*	*Silt*	*Clay per cent.*		
1	3	4	35	14	44	1·06	8·2
2	2	3	27	14	53	1·13	9·0
3	3	3	26	20	48	0·88	9·5
4	7	2	21	19	50	0·93	9·6
5	6	2	22	19	51	0·95	9·6
6	Hard cemented sand						

* The limits used for particle size are those of the international system:

Stones and gravel: diameter exceeds 2 mm.
Coarse sand ,, from 2 to 0·2 mm.
Fine sand ,, from 0·2 to 0·02 mm.
Silt ,, from 0·02 to 0·002 mm.
Clay ,, below 0·002 mm.

† pH is a measure of acidity or alkalinity, pH4 being strongly acid, pH7 being neutral, and pH10 being strongly alkaline.

Tables 1 and 2 afford a comparison between two plots. Plot G.21 contains no concretions, is of low salt-content, and is only moderately alkaline. Plot T.15 contains concretions (stones and gravel column), is of high salt-content, and is alkaline. This soil is very sticky when wet and is relatively infertile. A further illustration is given in Table 3, which contains some

laboratory data (averages for top 3 ft. of soil) and observations as to crop-yielding power. These observations are much less precise than the laboratory data. This is commonly the case, for accurate yield comparisons are obtained only by careful, long-continued, and costly experiments. On the other hand, the laboratory data refer only to the actual soil sample and this may not fairly represent the plot as a whole. It may be worth while to note at this point that skill and experience are needed if one is not to be misled by the imposing aspect of digits and decimals representing yields, analyses, or other data.

TABLE 3. *Estimates of Fertility and Laboratory Data (averages to 3-ft. depth) for 12 Irrigated Plots at El Bouga*

	Crop observations*				Soil data				
Plot	*Cotton*	*Wheat*	*Pea nuts*	*Sorghum*	*Stone and gravel per cent.*	*Clay per cent.*	*pH*	*Salts per cent.*	*Na/Clay (see text)*
U.T.	Good	Good	Good	Good	..	26	8·4	0·04	2
G. 21	Good	Good	Good	Good	..	32	8·4	0·04	2
G. 16	Good	Fair	Good	Fair	..	37	8·5	0·04	2
B. 64	Fair	Good	Poor	Fair	..	39	8·6	0·04	3
G. 47	Fair	Good	Good	Fair	..	48	8·9	0·07	8
B. 70	Poor	Good	Fair	Fair	..	40	9·2	0·07	11
W. 4	Poor	Fair	Poor	Fair	1	13	9·6	0·07	44
T. 18	Fair	Fair	Poor	Fair	..	36	8·3	0·78	43
H. 104	Poor	Fair	Poor	Fair	3	40	9·0	0·49	46
W. 8	Poor	Good	Fair	Fair	7	42	8·9	1·28	85
T. 15	Fair	Good	Good	Fair	2	48	8·9	1·02	71
Gh.	Nil	Poor	Poor	Nil	8	37	9·3	1·83	145

* The yield levels indicated by these observations are roughly as follows:

	Good yield	*Poor yield*	
Seed cotton (American type) .	1,400	700	lb. per acre
Wheat	1,600	700	or
Pea nuts	..	..	kg. per
Sorghum	1,700	700	hectare

It would for example be wrong to assume that the plots of Table 3 are arranged in order of fertility. The data are insufficient to justify comparisons between individual plots, although they do indicate that the less salty and less alkaline plots are on the whole more fertile than the others.

ED DUEIM lies on the White Nile about a hundred miles south of Khartoum. This river has a more even flow and carries less sediment than the Blue Nile, and its riverain deposits are normally more stable than those farther north. As it happens, however, a good deal of land in this area is being affected by the J. Aulia Dam. We are fortunate in having fairly extensive cotton yields and analytical data for an irrigated area of grey alluvial soil now lying a little above flood level. Tables 4 and 5 are given in illustration of land giving good and bad yields of long staple Egyptian cotton. How these soils compare in respect to other crops is not known. *Sorghum* (a grain) and *Dolichos* (a legume) are grown also, but they follow too soon after the cotton crop for the soil to exhibit its normal fertility.

TABLE 4. *Ed Dueim: Canal 5 West L: Fertile, deep, grey, clay. Cotton yield 118 per cent. of local average*

	Mechanical composition						
Ft.	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Salts per cent.*	*pH*	*Na/Clay (see text)*
1	8	13	10	68	0·05	8·6	5
2	3	12	10	74	0·08	8·7	10
3	3	9	10	79	0·32	8·1	13
4	3	8	11	78	0·59	7·5	15
5	2	7	6	85	0·61	7·4	13
6	3	6	7	84	0·52	7·5	13

TABLE 5. *Ed Dueim: Canal 5 West A: Less fertile, shallow, grey clay resting on sand bank. Cotton yield 55 per cent. of local average*

	Mechanical composition							
Ft.	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Salts per cent.*	*pH*	*Na/Clay (see text)*	
..	..	..	..	..	0·18	9·3	29	0–6 inches
1	16	35	6	41	0·81	8·2	46	6–12 ,,
2	13	31	9	47	0·63	8·6	53	..
3	12	26	8	55	0·69	8·3	53	..
4	33	39	5	23	0·36	9·0	55	..
5	42	35	4	16	0·22	9·5	53	..
6	40	51	2	6	0·13	9·9	62	..

TABLE 6. *Ed Dueim: Relation between cotton yield (per cent. of local average) and (a) clay content, (b) salt content, (c) soluble plus exchangeable sodium of top 3 ft. of soil*

Number of plots	*Mean cotton yield*	*(a) Clay per cent.*	*(b) Salts per cent. (top 3 ft.)*	*(c) Na/Clay*
4	186	70	0·15	11
4	146	73	0·07	10
4	121	64	0·26	18
4	110	61	0·11	12
4	79	54	0·46	30
4	70	53	0·40	32
4	62	51	0·37	34
4	44	45	0·31	30

Note: Salts are determined by a rapid conductimetric test. For explanation of column (*c*) see text.

Table 6 presents data for 32 plots grouped in fours in order of yield which is expressed as percentage of the average yield for this area. It appears that the high-yielding plots contain more clay and less salt than the low-yielding plots. In addition it is usually found that the high-

yielding plots are less alkaline than the plots of low yield. This difference, however, is less obvious because alkalinity is suppressed in the presence of salts. This is shown in the accompanying diagram which extends the data of Tables 4 and 5 by giving figures for 6-inch steps numbered in succession from the surface. Although these two plots differ greatly in mechanical composition, one being a deep clay whereas the other is shallow clay resting on a sandbank, both show reduced alkalinity in the more salty samples and it is clear that at corresponding levels of salt content the good plot is uniformly less alkaline than the bad one.

A valuable test for soils of this kind has been devised by O. W. Snow. The sample is shaken with ammonium chloride solution which dissolves not only the soil salts, consisting mainly of sodium sulphate and sodium chloride, but also the exchangeable sodium of the clay. As the latter is chiefly responsible for the alkalinity of the soil, this method of extraction discriminates between soils somewhat as is done in the diagram on p. 146. The total sodium in the extract is precipitated by a convenient reagent and is expressed so as many units (milli-equivalents) per 100 grammes clay. This method of expressing the data ignores the coarse particles of soil as being merely inert material which is indeed pretty much the case.

For the two soils of Tables 4 and 5 we thus obtain the following comparisons:

TABLE 7

Plot	*5 West L*	*5 West A*	*Dueim*
Cotton yield	118	55	per cent. of average
Average clay to 3 ft. . .	74	48	per cent.
pH when salts = 0 . .	9·0	10·0	..
Average salts to 3 ft. . .	0·15	0·61	per cent.
Average sodium test to 3 ft. .	10	48	m. eq. per 100 g. clay

The right-hand column of Tables 3, 4, 5, and 6 gives further representative figures, and it is clear that the more fertile soils have the lower sodium values. The figures range from a few units in the most fertile land to over 100 units in 'black alkali' soils. These fortunately are of rare occurrence, being limited to dark-coloured oily-looking patches where there has been much seepage and evaporation.

7. ANALYTICAL DATA FOR SOME TYPICAL NON-ALLUVIAL SOILS

It is a difficult matter to present briefly the very extensive analytical data which accumulate when soils are examined. Tropical soils are usually deep and, as a rule, we find it convenient to sample them to a depth of 6 ft. in 6-in. steps, the sampling interval being altered if necessary to fit any obvious layer in the soil profile. When the mechanical composition of the samples has been determined and a few other tests have been made the soil profile, which is the subject under examination, is represented by about 100 analytical values which are expensive to print and are hardly glanced at by most readers. Nevertheless ten tables (numbers 8–17) are given herewith to illustrate the range of soil properties included between

the grey cloddy clay of the Alkaline catena which is the most widely distributed soil of the Sudan and the attractive Red Loams found near the Uganda border.

It has been noted that silica dissolved from rock fragments on the high land is carried on to the plain and remains there when the water evaporates. It is not surprising therefore that the proportion of silica in the clay of the low-lying areas should be greater than that of higher lying land, and much greater than that of clay in humid tropical regions. The ratio of silica to alumina in the clay of a soil is accordingly a useful analytical criterion, but it is available only to the skilled chemist. Somewhat analogous information is given by a simple physical test. If 20 gm. air-dry fine soil be placed in a wide-mouthed 4-oz. bottle it will form a shallow layer of about 8 c.c. actual volume. If water (100 c.c.) be added and the bottle be shaken for a moment and then allowed to stand the volume of sediment will usually be between 20 and 40 c.c., being small for a sandy or non-plastic soil and large for a heavy and plastic one. In Tables 8–17 figures so obtained are shown in the column headed 'sed. vol.' and indicate the readiness with which these soils absorb water under the conditions of the test. The differences are magnified by adding to the bottles 10 c.c. of 10 per cent. sodium carbonate solution, which has little effect on non-plastic soils, but gives notably large sediment volumes (column headed 'SED. VOL.') in the case of plastic soils. With the Chalemni samples, for instance, sediment then fills the available space (8+100+10 c.c.) and the mixture sets to a turbid jelly on standing. It should be noted that a soil which swells in this laboratory test will do so in the field also and will thereby close channels and crevices and hinder deep penetration of water, whereas a soil which does not swell in the laboratory test will be readily permeable in field conditions because its pores and cavities will remain open.

A large number of fairly simple physical tests may be used to distinguish one soil from another, but it is well to note that it is sometimes difficult to gauge the behaviour of the soil in the field from tests carried out in the laboratory. In the field the particles of soil are linked together to form a more or less complicated structure having well-marked physical properties. This structure is altered or destroyed when samples are prepared for laboratory examination, the change being greater with plastic than with non-plastic soils because the former are often cloddy whereas the latter have in the field an open structure which more nearly resembles the closely packed laboratory sample.

The soils of the 'alkaline catena' are represented by two examples in Tables 8 and 9. These soils are more stable than the riverain deposits just discussed simply because the clay plain is so vast in comparison with the seasonal streams which rush down from the hills carrying much suspended matter. These maintain for some distance a meandering channel but then peter out in a flat expanse which is flooded during the rains but waterless thereafter. A supply of water is obtained either by making ponds near the hill foot to hold back the flood-water or by sinking wells in the valleys. For the latter purpose it is desirable to maintain a good cover of vegetation on the hill slopes and along the fringe of coarse detrital soil. If this

vegetation is removed by fire or cutting, the rain-water runs off the hills too quickly and has less chance to sink into the ground. At the same time there is increased erosion and the fertile soil near the hill foot is carried out into the plain where lack of drinking-water makes it difficult to harvest a crop.

The soil at Chalamni (Table 8) is a grey alkaline clay of low salt-content (average to 6 ft., 0·06 per cent.) and consists of fine material washed down by a nearby hill. The soil is sticky when wet and cracks deeply on drying, forming hard tough lumps. In the top foot, however, there is a tendency to horizontal cleavage indicating the manner of deposition, but below this depth the soil can be crumbled into little wedge-shaped units. These seem to be bounded by slip surfaces caused by swelling and shrinking of the soil due to changes in moisture content. When a pit has been dug the main slip surfaces can often be seen running steeply into the soil to a depth of several feet. The yearly inflow of rain-water is sufficient to wash calcium carbonate out of the top soil and this separates at depth in conspicuous white concretions partly soft and partly hard. Thus in Table 8 the stones and gravel of foot 6 consist mainly of hard concretions, but the fine soil, separately analysed, also contains 7·1 per cent. of calcium carbonate. Where water stands for a long time the calcium is leached to greater depth and the soil is then bluish-grey, tough, moderately alkaline, salt-free, but unsuited to crops owing to its low situation.

The soil sampled at Liria (Table 9) resembles that at Chalamni but is less heavy and less alkaline. A little further up the slope one would expect to find a dark brown fertile soil only moderately heavy and weakly alkaline. This higher-lying member of the 'alkaline catena' would probably contain less concretionary calcium carbonate, but more rock fragments than were found in the pit actually sampled.

Tables 10 (Rumbek 'toich') and 11 (Yirol 'toich') give data for two soils of the flood plain built up of fine material carried northwards by sheet erosion from the ironstone country along the Nile Congo divide. These might be classed as alluvial soils, but they are more conveniently grouped with the higher-lying members of the 'toich catena'. The soils of the flood plain vary in mechanical composition. Near the surface the soil is usually weakly acid and has much iron-stain along the channels left by grass roots. If heavy the soil cracks deeply during the dry season but remains wet at depth, and a dark sludge is forced through cracks and cavities as the soil blocks settle. The subsoil is usually alkaline, but Table 11 shows that this is not always so. After treatment with sodium carbonate the Yirol 'toich' samples have large sediment volumes; the Rumbek 'toich' samples, however, have comparatively small sediment volumes after this treatment. The contrast is a little surprising and is not wholly explained by the different clay content of the two soils. It is perhaps an expression of the fact that these flood soils lie between the leached, non-plastic, more or less acid soils of the ironstone plateau and the saturated, plastic, alkaline clay plains which are formed in drier regions.

Tables 12 (Halima) and 13 (Mboro) are given in illustration of two other soils of the 'toich catena'. Halima represents the lower-lying slopes

of leached soil usually pale in colour but having yellow-red patches of iron-stain or darker manganese patches. Mboro is a dark red cultivated soil lying at the foot of a hill capped with ironstone. It represents the more fertile upper slope, and it will be noted that its content of nitrogen, which is an index of root development, exceeds that of the pale Halima soil. The iron concretions (pea iron) of these soils appears to be detrital.

Table 14 (Y-ei) illustrates a soil of the 'ironstone catena'. As a museum specimen a block of soil 2 metres deep was cut half-way down the slope of a hill on the top of which bare ironstone was exposed. At this spot pea iron occurs in a thick layer, and its detrital nature is proved by the inclusion in this specimen of a detached lump of ironstone resembling that at the hill-top. The moist pale, somewhat plastic, subsoil contains many channels used by termites, and localized separation of iron oxide occurs around these channels. This is noticeable also at the foot of the hill and is there associated with a fluctuating water-table from which it appears that the separation of iron is a consequence of evaporation occurring during the dry season. This mottled subsoil, riddled with termite cavities, has a striking resemblance to the hard sheets of vesicular ironstone often exposed in this region. This suggests that the ironstone sheet was at one time a part of the subsoil and has been exposed by soil erosion and hardened by desiccation causing irreversible separation of iron.

The ironstone plateau is not, however, uniformly eroded, and Table 15 (Gungura) illustrates a normal fertile and closely cultivated soil of this kind. The samples were taken from the village of Gungara, a chief of the Zande tribe. The rather similar data of Table 16 (Yubo) are of interest in that this deep red loam occurs in an area which, at first sight, seems to be uniformly capped with a thick sheet of ironstone. On geological grounds G. Andrew regards the ironstone of the Sudan as a lateritic sheet marking a mid-Tertiary peneplain. It has since been dissected, which can well be seen near the Nile Congo watershed. There erosion and deposition have given soils of which examples are shown in Tables 10, 11, 12, 13, and 14. Not all the soils are eroded, however, and Tables 15 and 16 are examples of soils which seem to have been formed *in situ* from previously weathered material. They closely resemble the soil of Table 17. Table 17 gives data for samples taken from Lotti Forest on the lower slopes of the Acholi Hills. This red loam formed, it is assumed, directly from rock seems hardly to be distinguished from the soil represented in Table 16 derived from previously weathered material. Nevertheless a closer examination of the area and inspection of the samples for presence of resistant minerals would probably reveal significant differences.

8. Warning

The reader should note that information such as is contained in Table 6, which refers to a square mile or so of salty, irrigated land, demands years of carefully controlled agricultural work, combined with years of laboratory experience. Only a minute part, perhaps 0·03 per cent., of the Sudan has so far been studied in this detailed fashion. For about 99·97 per cent. of the Sudan we are guided by the observations and route reports of a few

TABLE 8. *Chalamni* (4° 28′ N., 32° 52′ E.; 1,900 ft.)

Silica/alumina ratio of top foot clay 4·43. Moderate crop of American cotton; natural vegetation, tall grass and Acacia

	Mechanical composition per cent.					Data for fine soil						
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent. CaCO₃*	*pH*	*c.c.* sed. vol.*	*c.c.†* SED. VOL.	*Per cent. nitrogen*	
1	1	6	20	8	63	0·04	..	8·0	26	118	0·05	Grey, slight horizontal cleavage.
2	1	5	19	10	63	0·05	..	8·3	29	118	0·03	Grey, slightly plastic, closely packed, wedge-shaped units some flattened roots.
3	1	4	17	10	66	0·07	trace	8·7	37	118	0·04	
4	..	3	13	9	72	0·07	trace	8·6	37	118	0·04	
5	1	2	13	7	75	0·08	1·1	8·8	43	118	0·03	Pale grey, friable, calcareous.
6	14	4	14	9	59	0·08	7·1	9·0	43	118	0·02	..

TABLE 9. *Liria* (4° 40′ N., 32° 06′ E.; 1,900 ft.)

Silica/alumina ratio of top foot clay 3·38. Usually cultivated; natural vegetation, tall grass.

	Mechanical composition per cent.					Data for fine soil						
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent. CaCO₃*	*pH*	*c.c.* sed. vol.*	*c.c.†* SED. VOL.	*Per cent. nitrogen*	
1	1	9	30	6	51	0·03	..	7·2	24	64	0·09	Grey, closely packed, wedge-shaped units, slightly plastic. (A few flattened roots.)
2	1	7	30	6	53	0·04	trace	7·7	29	70	0·07	
3	2	7	29	6	54	0·05	0·2	8·2	29	75	0·06	
4	5	7	24	7	56	0·06	0·2	8·4	27	90	0·05	
5	3	6	22	7	61	0·07	0·7	8·6	33	92	0·05	

* *sed. vol.* = sediment volume of 20 gm. fine soil.

† SED. VOL. = ditto after treatment with Na_2CO_3.

TABLE 10. *Rumbek 'Toich'* (6° 51′ N., 29° 48′ E.; 1,600 ft.)

Silica/alumina ratio of top foot clay 2·56. Grazing land; natural vegetation, tall grass.

	Mechanical composition per cent.					Data for fine soil						
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent. $CaCO_3$*	*pH*	*c.c.* sed. vol.*	*c.c.† SED. VOL.*	*Per cent. nitrogen*	
1	6	36	31	6	18	0·01	..	6·3	17	21	0·06	Pale grey, cloddy, in dry season.
2	7	33	21	4	35	0·01	..	6·8	19	33	0·04	Iron stain.
3	10	28	18	5	38	0·01	..	7·5	19	37	0·03	Grass roots to 3 ft.
4	11	35	13	4	37	0·02	..	8·1	22	37	0·02	..
5	8	34	17	4	36	0·01	..	8·3	22	41	0·02	Dark sludge at depth
6	8	38	13	5	35	0·02	trace	8·3	24	45	0·01	

TABLE 11. *Yirrol 'Toich'* (6° 32′ N.; 30° 29′ E.; 1,600 ft.)

Silica/alumina ratio of top foot clay 2·50. Grazing land; natural vegetation, tall grass.

	Mechanical composition per cent.					Data for fine soil						
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent. $CaCO_3$*	*pH*	*c.c.* sed. vol.*	*c.c.† SED. VOL.*	*Per cent. nitrogen*	
1	0	0	10	7	81	0·03	..	6·2	26	63	0·13	Grey, cloddy in dry season.
2	0	0	13	9	76	0·01	..	5·8	25	79	0·07	Diffuse iron stain.
3	0	0	10	9	80	0·01	..	5·6	25	101	0·06	Many grass roots.
4	0	0	11	9	79	0·01	..	5·5	26	118	0·05	Dark sludge at depth. Some
5	0	0	20	9	69	0·01	..	5·5	23	92	0·05	grass roots.
6	0	1	25	8	66	0·04	..	5·7	24	100	0·04	

* *sed. vol.* = sediment volume of 20 gm. of fine soil.

† SED. VOL. = ditto after treatment with Na_2CO_3.

TABLE 12. *Halima* (7° 37′ N., 27° 57′ E.; 1,700 ft.)

Silica/alumina ratio of top foot clay, 2·46. Sometimes used for grain crops; natural vegetation, short grass and trees (Combretaceae, Caesalpiniaceae)

	Mechanical composition per cent.					*Data for fine soil*						
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent. $CaCO_3$*	*pH*	*c.c.* sed. vol.*	*c.c.*† SED. VOL.	*Per cent. nitrogen*	
1	1	23	55	6	12	0·01	..	5·8	15	20	0·04	Pale grey, porous to 6 ft.
2	2	23	45	8	22	0·01	..	5·1	14	20	0·02	
3	1	23	37	8	31	0·00	..	5·1	15	26	0·02	White with yellow-red iron patches.
4	4	21	30	8	36	0·01	..	5·3	17	26	0·02	
5	4	17	29	7	42	0·00	..	5·5	17	27	0·02	
6	includes pea iron layer					0·00	..	5·8	20	28	0·02	

TABLE 13. *Mboro* (7° 43′ N., 27° 42′ E.; 1,700 ft.)

Silica/alumina ratio of top foot clay, 2·22. Cultivated land; natural vegetation, light forest (Combretaceae, Caesalpiniaceae)

	Mechanical composition per cent.					*Data for fine soil*						
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent. $CaCO_3$*	*pH*	*c.c.* sed. vol.*	*c.c.*† SED. VOL.	*Per cent. nitrogen*	
1	6	26	26	5	35	0·01	..	6·5	16	21	0·06	Dark red, massive Termite chambers at 1, 2, and 5 ft.
2	3	16	20	6	55	0·01	..	5·8	20	25	0·05	
3	5	18	17	7	52	0·01	..	6·1	19	28	0·04	
4	9	18	15	8	49	0·01	..	6·3	19	28	0·03	Red with black Mn patches.
5	11	21	15	9	45	0·01	..	6·6	19	28	0·03	
6	14	19	16	7	43	0·01	..	6·9	18	27	0·02	Pea iron layer.

* *sed. vol.* = sediment volume of 20 gm. of fine soil. † SED. VOL. = ditto after treatment with Na_2CO_3.

TABLE 14. *Yei* (4° 06′ N., 30° 40′ E.; 2,700 ft.)

Silica/alumina ratio of top foot clay, 2·24. Cultivated land; natural vegetation, forest.

	Mechanical composition per cent.					Data for fine soil						
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent. $CaCO_3$*	*pH*	*c.c.* sed. vol.*	*c.c.† SED. VOL.*	*Per cent. nitrogen*	
1	7	23	45	5	19	0·01	..	6·1	17	23	0·05	Dark grey.
2	..	..	..	..	..	0·01	..	6·5	..	..	0·05	Brown.
3	63	Layer of red pea iron is probably wholly detrital as it includes detached lumps of ironstone										Termite chambers at 3 in., 15 in., 21 in., and 54 in.
4	64											
5	..											Moist, channelled, pale with localized Fe stain.
6	5	10	27	12	45	0·01	..	6·5	26	29	0·03	

TABLE 15. *Gungura* (4° 28′ N., 28° 27′ E.; 2,100 ft.)

Silica/alumina ratio of top foot clay, 2·02. Cultivated land; natural vegetation, forest.

	Mechanical composition per cent.					Data for fine soil							
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent. $CaCO_3$*	*pH*	*c.c.* sed. vol.*	*c.c.† SED. VOL.*	*Per cent. nitrogen*		
1	4	34	33	6	20	0·02	..	5·9	17	22	0·08	Grey.	Iron stain increases with depth and forms friable concretions.
2	8	31	26	6	29	0·01	..	5·5	17	20	0·04	Brown.	
3	13	24	21	5	37	0·00	..	5·5	20	23	0·04	Light red, friable and minutely porous.	
4	12	16	25	9	37	0·00	..	5·8	21	24	0·03		
5	10	13	26	13	37	0·00	..	6·1	21	22	0·02		
6	9	11	24	14	41	0·00	..	5·8	20	23	0·02		

* *sed. vol.* = sediment volume of 20 gm. of fine soil.

† SED. VOL. = ditto after treatment with Na_2CO_3.

TABLE 16. *Yubo* (5° 24′ N., 27° 15′ E.; 2,500 ft.)

Silica/alumina ratio of top foot clay, 2·16. Land cleared to guard against sleeping-sickness; natural vegetation, forest.

	Mechanical composition per cent.					Data for fine soil						
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent.* $CaCO_3$	*pH*	*c.c.* sed. vol.*	*c.c.†* SED. VOL.	*Per cent. nitrogen*	
1	5	33	40	2	17	0·02	..	6·0	16	19	0·08	Grey sandy loam.
2	6	39	27	1	25	0·02	..	4·9	16	19	0·04	Red loam.
3	7	34	23	1	33	0·01	..	4·8	20	22	0·04	,,
4	4	25	26	2	42	0·02	..	4·9	21	24	0·04	,,
5	4	27	21	3	44	0·01	..	5·0	21	24	0·03	,,
6	4	20	24	5	45	0·02	..	5·0	21	24	0·03	,, ; some roots.

TABLE 17. *Lotti* (4° 02′ N., 32° 33′ E.; 3,000 ft.)

Silica/alumina ratio of top foot clay, 1·94. Catchment area carrying rain forest

	Mechanical composition per cent.					Data for fine soil							
Ft.	*Stones and gravel*	*Coarse sand*	*Fine sand*	*Silt*	*Clay*	*Per cent. salts*	*Per cent.* $CaCO_3$	*pH*	*c.c.* sed. vol.*	*c.c.†* SED. VOL.	*Per cent. nitrogen*		
1	3	24	31	7	32	0·03	..	7·1	20	23	0·11	Grey	Whole column is moist, very friable minutely porous loam. Tree roots to 6 ft.
2	3	18	23	3	52	0·02	..	6·3	21	25	0·07	Bright red	
3	2	15	20	4	57	0·02	..	6·1	21	28	0·06	,,	
4	2	17	19	3	57	0·01	..	5·7	21	27	0·05	,,	
5	3	18	19	3	56	0·01	..	5·2	21	24	0·04	,,	
6	3	18	19	3	56	0·01	..	4·9	21	27	0·04	,,	

* *sed. vol.* = sediment volume of 20 gm. of fine soil.

† SED. VOL. = ditto after treatment with Na_2Co_3.

officials and by the examination of occasional soil samples. To spread little butter over so large a slice of bread we have used theories v relate soil formation with climate, topography, and parent material. present account of Sudan soils is therefore largely speculative and is liabl to revision as the theories change and as new facts accumulate.

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CHAPTER IX

TRANSPORT IN THE SUDAN

By G. F. MARCH, M.C., 4 N, DIP. AGR. (Wye)
Director of Agriculture and Forests (as from June 1944)

IN a country so large as the Sudan, the productive areas of which are so scattered, and the unproductive tracts so vast, the question of transport looms very large when the initiation or development of any industry is under consideration. Its great distance from the sea has, no doubt, been the chief reason for the lack of development in Equatoria where considerable areas of fertile country are to be found. For a commodity to be worth

FIG. 67. General view Port Sudan harbour. Coal transporters right foreground (*photo Sudan Railways*).

producing for export the essential feature must be high cash value per unit of weight. The advent of the cheap American motor-lorry has placed many up-country areas on the map as regards economic production, and, doubtless, the development of the diesel-engined and of the gas-producer types of lorries will be of enormous benefit in that respect in due course.

PORTS

The main port of the country is Port Sudan. Situated on the Red Sea about 850 miles south of Suez, it is a well-protected natural harbour with a good anchorage. It is provided with 2,280 ft. of main quays for the handling of general cargo, well equipped with cranes and with adequate warehouse accommodation. In addition four special berths are provided; two of them are allotted to the coal and bunker trade and are equipped with four electrical coal transporters; the third berth is used for salt and other bulk cargoes, and the fourth is used for handling dangerous petroleum in bulk and is fitted with a pipe-line to the oil installations. Special berths for handling cargo discharged by lighter are also available. All berths are served by rail with a network of rail sidings running the full length of the quays. During 1938, 1,153 ships used the port and 746,591 tons of cargo in and out and 4,889 passengers were dealt with. The port is administered by the Sudan Railways.

Though Suakin, a little farther to the south, was quite a busy harbour before Port Sudan was developed, it is now very little used except by the 'sambūk'.

Anchorages, but practically nothing in the way of quay facilities, exist for small craft and native sailing-boats at Trinkitat and Aqiq on the Red Sea. Most of the Tokar cotton crop is usually taken by small steamer or 'sambūk' (native sailing-craft) from Trinkitat to either Suakin or Port Sudan for ginning.

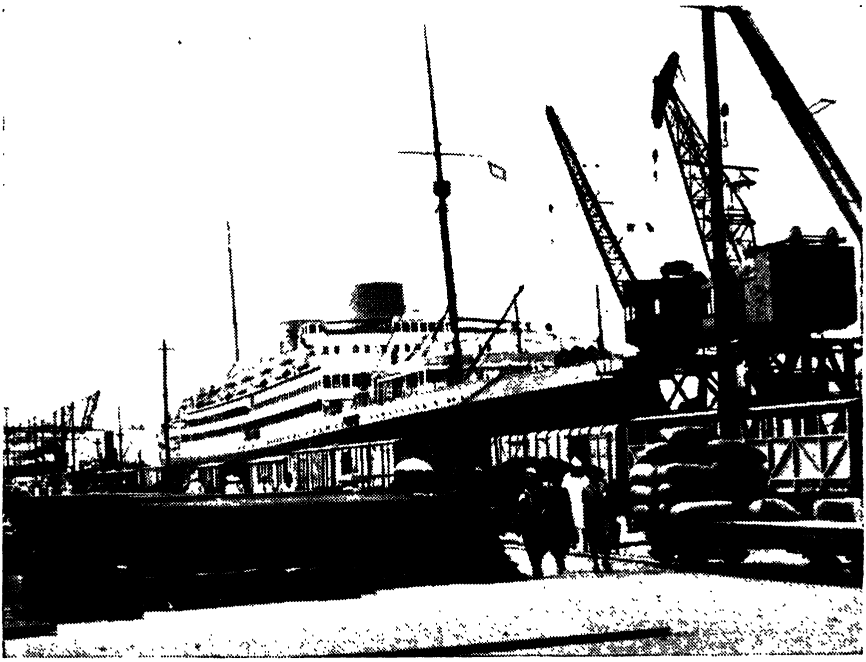

FIG. 68. Port Sudan quays—showing electric cranes (*photo Sudan Railways*).

The port for inland traffic between the Sudan and Egypt is Wadi Halfa. The river is not navigable by through traffic between Khartoum and Wadi Halfa, but a river service operated by the Sudan Railways Administration connects Wadi Halfa, which is the northern terminus of the Sudan Railways, with Shellal, the southern terminus of the Egyptian State Railways. In 1938 this service dealt with 47,855 passengers and 22,564 tons of traffic.

In the south the main terminus port is Juba near the Uganda border. A good modern road, 122 miles in length, over which motor transport services operate connects this port with Nimule, the northern (steamer) terminus of the Kenya and Uganda Railways system. A second border port concerned with trade with the Sudan is Gambeila, just over the border in Abyssinia.

RAILWAYS

The main railway system, which is Government owned, is of 3 ft. 6 in. gauge. It is a single line with a route mileage of 2,014 (3,243 km.) and a

track mileage of 2,297 (3,699 km.). In 1938 the total tonnage transported was 880,857 tons, while 1,275,298 passenger journeys were made.

From Port Sudan the line has to climb to about 3,000 ft. in order to cross the Red Sea Hills. Until it reaches Ātbara (474 km.) it passes through unproductive country. From Sallom, however, a small branch line connects the port of Suakin with the main line. A secondary line (802 km. long) takes off at Haiya Junction and serves the Eastern Sudan, running via Kassălă and Gedāref to link up with the main line again at Sennār. The Kassălă area is the source of the very high-quality long-

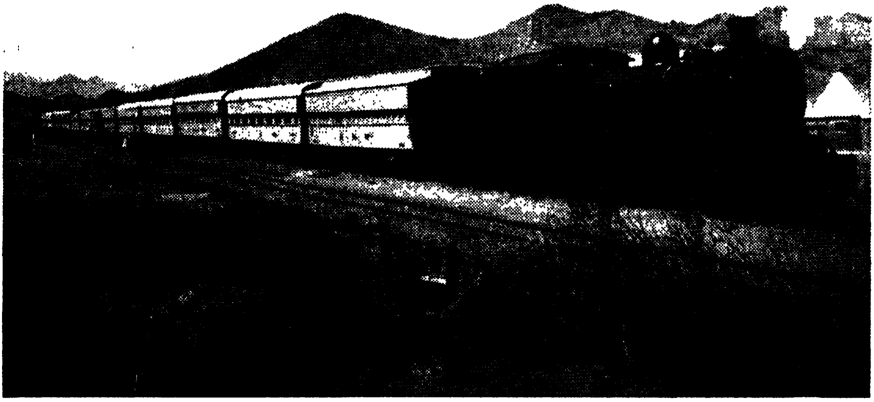

FIG. 69. Mail train, Sudan Railways, in Red Sea Hills (*photo Sudan Railways*).

stapled cotton grown in the delta of the river Gash. The Gedāref area exports considerable quantities of gum arabic, simsim (*Sesamum orientale* Linn.), and dura (*Sorghum* sp.).

Wadi Halfa is connected to Ātbara (611 km.) by a line which crosses an almost rainless desert during its first 367 km. At this point Abu Hāmed is reached and a branch line from Kareima (248 km. long) which serves the wheat- and date-producing Merowe/Dongola district joins it. From Abu Hamed the line runs parallel with the Nile and meets the line from Port Sudan at Ātbara.

From Ātbara, which is the headquarters of the Railways Administration, the line continues parallel to the Nile until Khartoum North is reached. It then crosses the Blue Nile by a large bridge to Khartoum.

South of Khartoum the line follows the Blue Nile to Sennār, passing through the main cotton-growing area known as the Gezira and its chief town Wad Medănĭ. From Sennar it strikes almost due west to Kosti and El Obēid. The White Nile is crossed by bridge a few miles before Kosti is reached. Between Kosti and El Obēid the line passes through an area which produces considerable quantities of dura, cattle, gum arabic, simsim, ground-nuts, and rain-grown American-type cotton. The distances

by rail from Khartoum to Wad Medănī, Sennār, Kosti, and El Obēid are 174, 270, 382, and 689 km. respectively.

A light railway, which is operated by the Sudan Railways, connects Tokar with Trinkitāt. Its function is to carry the Tokar cotton crop and it only operates during the cotton season.

Another light railway is operated in the Gezira by the Sudan Plantations Syndicate. It serves the cotton-growing area supervised by that company, and its main function is the transport of seed-cotton from the field to the ginning centres at Meringān near Wad Medănī and at Hassahēissa.

STEAMERS

The river steamer services are also operated by the Railways Administration and act as feeder services or extensions to the railway system.

The principal services are those operating on the White Nile between Khartoum, Kosti, and Juba. Kosti is a well-equipped river port 320 km. river distance from Khartoum and is situated also on the main railway line. Juba, the terminus of the service, is 1,755 km. from Khartoum. Through cargo services operate from Khartoum to Juba, but the principal mail and passenger services (also some cargo services) operate between Kosti and Juba, the journey between Kosti and Khartoum being made by rail. Local passenger steamer services are run between Khartoum and Kosti. The total upstream journey to Juba takes 13 days; downstream the journey takes only 8 days.

Small seasonal branch services go up the Sobat river to Gambēila (Abyssinia) and up the Bahr El Ghazal and Jur rivers to Meshra Er Req and when possible as far as Wau.

In 1938 goods handled by all the steamers services on the southern reaches amounted to 48,973 tons; 28,153 passengers were carried.

The next largest service is that running between Wadi Halfa and Shellāl. Details of it have already been given under the heading 'Ports'.

A small service runs on the Blue Nile from Suki on the Gedaref line to Roseires (210 km. distant), handling (in 1938) 9,322 tons of goods.

Another service runs on the main Nile (south of Wadi Halfa) from Kareima, the terminus of the line from Abu Hāmad to Kerma (335 km. distant). In 1938 this service handled 11,245 tons of goods and 31,384 passengers.

From the above all too brief details it will be seen that the transport system of the country is good and at the Sudan's present stage of development adequate for its needs.

RATES (RAIL AND STEAMER SERVICES)

The rating policy of the Sudan Railways Administration follows the world-wide practice of railways, whether State or privately owned, of spreading the charges for services rendered as far as possible according to the ability of the traffic to bear such charges and, in furtherance of that policy, providing a wide variation in the tariff charges for different classes of traffic. In some respects rating is made more difficult by the fact that the Sudan is entirely an agricultural country, with no heavy industries,

relying on its exports of agricultural produce for its economic prosperity. The areas of production are remote from the sea and therefore much long-distance haulage and empty running is involved, yet a considerable proportion of the crops produced is of relatively low value in the world's markets and can only stand very cheap rates. Consequently much careful grading and adjustment of charges both on imports and exports are necessary.

The tariff provides a scale of fifteen class rates. These rates are tapered so that in effect the longer the distance the traffic is hauled the smaller the charge per ton-kilometre. At 800 km. (the distance Port Sudan to Khartoum) the rate per ton-kilometre varies from 17·75 m/ms. for Class 1 to 1·5 m/ms. for Class 15. Superimposed on these class rates is a wide range of exceptional and temporary rates, cheaper than the standard charges, principally for the carriage of agricultural products; these special rates are added to or amended from time to time to meet changes in trade conditions. Such a wide variation means that while a certain portion of traffic is carried at above average charges a good deal is carried at below average charges and even below average costs. The principle of the tapering rate applied to both exports and imports is of great assistance in encouraging development in the more distant producing and consuming areas.

As an indication of the long distances involved it may be mentioned that the average haul by rail of all commodities is no less than 773 km. (480 miles); it is considerably greater in the case of all the principal exports, whilst produce of the Southern Sudan has to travel over 2,000 km. (1,243 miles) before it reaches the sea.

Some examples of rates per metric ton are: *Imports*, Port Sudan–Khartoum (800 km.), textiles, £E.11.900 m/ms.; provisions £E.4.900 m/ms.; agricultural machinery, £E.2.300 m/ms.; cement, £E.1.200 m/ms. *Exports* to Port Sudan from principal producing areas: gum 'hashab' from El Obēid, £E.6.250 m/ms.; cotton (American) from any rail or river station, £E.5.000 m/ms.; cotton (Sakelleridis) from Meringān, £E.6.600 m/ms.; sesame from Suki, £E.3.300 m/ms.; oilcake from Umm Ruwāba, £E.1.700 m/ms.; dura (cleaned at Port Sudan) from any rail station, £E.1.000 m/ms.; ground-nuts from Tendelti, £E.1.800 m/ms.; hides from El Obeid, £E.4.100 m/ms. These rates exclude any temporary war surcharge.

Although separate tariffs are provided for the steamers' services they are treated as an integral part of the railways system and the charges for transport are framed accordingly. For instance, on the southern reach (which is the main service) the rates are an extension of the railway rates taper so designed that traffic to and from the distant undeveloped southern areas is carried as cheaply as possible; agricultural machinery, for example, pays about £E.4.800 m/ms. per ton from Port Sudan to Juba, a haul of 2,555 km.

Within certain wide limits the heavier the traffic which the railways have to carry the less the costs of transport, in turn enabling the undertaking to reduce its charges: thus the agricultural and economic progress of the country and the well-being of the Sudan Railways march hand in hand.

Roads

It is only in the large towns such as Khartoum, Omdurman, Wad Medănĭ, and Port Sudan that tarmac roads comparable in any way to those in Great Britain are to be found.

A network of roads of varying suitability for mechanical transport is, however, now in existence all over the country. For the most part the roads are merely dirt tracks which are liable to be rendered impracticable for motor traffic by heavy rain. In the northern third of the Sudan rains are generally light, consequently motor traffic is not usually held up for more than a few days at a time. In the middle third, however, there is generally a hold-up of from 3 to 5 months during the rains which fall from June to October. In the southern third, where rainfall is heavy and prolonged, greater efforts have perforce been made to produce all-weather roads. Several of the main roads in Equatoria (e.g. Juba–Nimule, Juba–Belgian Congo) are passable the whole year round. They have been carefully sited, cambered, and have good gravel surfaces which are continually under supervision and repair. They are also provided with permanent bridges. Many of the other roads in this province are provided with semi-permanent bridges and motor traffic is only as a rule held up for short periods after heavy rain.

The road between El Obeid and Darfur traverses heavy sand for many miles. Sand is also encountered in other parts of Kordofān and in parts of Northern and Kassălă provinces. The use of over-size balloon tyres is of great assistance under these conditions.

Forms of Transport

In addition to the railways and river steamers many other forms of transport are in use.

Motor-lorries

These have been mentioned in the opening paragraph of this chapter. Their introduction has had a marked effect on the general economics of the country, and the administration has latterly been based largely on the ability of the staff to cover long distances in a short time by means of this form of transport. Too great a reliance on motor transport has its disadvantages in time of war due to the consequent shortages of petrol, spares, and replacements. The development of gas-producer lorries referred to previously may offset the first of these disadvantages and may also result in reduced fuel costs.

In the tsetse-fly areas of Equatoria motor transport is the only alternative to head-carriage. In other provinces, where animal transport was the rule in the past, lorries have become very popular. They enable a cultivator to accompany his produce to market and return home all in one day where previously an absence of several days was necessary.

The remarkable aspect of the native-owned motor transport is the low freight rates charged. They are able to compete favourably with rates charged for animal transport. Some recent contract rates for the transport

of baled lint cotton from Nuba Mountain ginneries to rail- or river-head are quoted below:

1937/8 Season

Transport rates applicable to transport of ginned cotton by *lorry or by camel* at the option of the contractor. (In fact he used lorries almost entirely except for the carry from Kalōgi to Kāka.)

	Approx. distance in miles	Rate in milliemes	
		per kantar (100 rotl)	Per tonne-mile
Kadugli–El Obeid . .	190	100	11·7
Dilling–El Obeid . .	98	65	14·8
Lagowa–El Obeid .	187	115	13·7
Umm Berembeita–Rahad	63	45	15·9
Abu Geheiha–Rahad .	112	75	14·9
Talodi–Tonga . .	99	95	21·4
Kalogi–Kaka . .	87	102	26·1

One pound sterling is the equivalent of 975 milliemes; the above tonne/mile rates are therefore the equivalent of a range of from 2·88d. to 6·44d. per tonne/mile.

The first five rates quoted above do not vary very materially. The reason for the last two being considerably higher is that roads are bad and return loads are very few.

Camels

For long carries, and where time is of no great importance, the pack or 'hamla' camel is very suitable. The southern third of the Sudan is, however, not camel country, and the animal is unsuitable for use during the rains in those parts of the northern two-thirds of the country which have a rainfall of about 20 in. or more.

Camel transport contractors are available in most districts except in the south. They are, on the whole, surprisingly reliable. If they fail it is not usually in the safe delivery of goods entrusted to them, but rather in inability to provide a sufficiency of animals at the required time.

When large contracts for transport by camel are put out to tender, it is most important that as much time as possible should be allowed between the award of the tender and the commencement of work. When camels are required by the dozen they can usually be found locally by the contractor without much difficulty, but when they are required by the thousand it may be necessary for the contractor, or his agents, to make protracted tours amongst the camel-owning tribes in order to make agreements with the local 'khabir' (sub-contractors) to produce the required camels at the appointed time and place. This usually entails the payment by the contractor of cash advances ('arbūn'). He will also probably have to supply ropes for tying the loads on to the pack-saddles ('hawāya'), and also a ration of tea, sugar, and perhaps grain to the camelmen before they start their journey. It will be seen therefore that it should not be considered

unreasonable if the contractor asks for payment in advance of part of the money to which he will be entitled on completion of his contract.

The pack-saddles can be adapted for the carriage of such loads as stone, brick, firewood, and the large sacks used for the transport of seed-cotton in the Gezira. These adaptations are effected by the construction of varying forms of cradles permanently fastened on each side of the saddle. The basis of these cradles is usually some form of forked stick, the longer side of which is attached to the saddle. The bottom of the cradle is usually therefore 'V'-shaped.

FIG. 70. Camels carrying packs of unginned cotton in the Gezira.

Provided loads are compact and well balanced, camels will carry 500 lb. for long distances (100–200 miles). Some camels are, of course, able to carry more than others; it is convenient therefore if packages vary in weight between 200 and 300 lb., thus allowing the camels employed to carry loads of 400 to 600 lb. according to their individual capacity.

Bulls

Many of the cattle-owning Arab tribes (Bagāra) use their bulls for pack transport. They are capable of carrying about 100 lb. on each side of the saddle ('safīna'). For short journeys rather more can be carried if the load is compact and well balanced. The latter is most important as the saddles have no girths and are only kept in place by balance. A man, woman, or boy usually rides on top of the load in order to keep it balanced. This is especially necessary over rough country.

Though bulls are commonly used for drawing ploughs, the use of a bull cart is practically unknown except in Government stations in connexion with the sanitary, or other, services.

River sailing-craft (Merkab)

Native-built sailing vessels made of sunt (*Acacia arabica* Willd.) are in common use on the river. They are of varying sizes and are classed

according to the number of ardebs of grain which they can carry. Common capacities run from 50 to 300 ardebs.

When fully loaded they have very little freeboard and are consequently very susceptible to wave action. Where the Nile is abnormally wide on the upstream side of a dam, waves attain considerable size in a high wind. These merkab can only sail with the wind, they are unable to beat into it. Roughly speaking this means that they can only sail upstream in the winter when the wind is in the north. When travelling against the wind they have to be towed or poled by hand unless they are moving in the same direction as the current. Experiments in the building of Egyptian-type sailing-

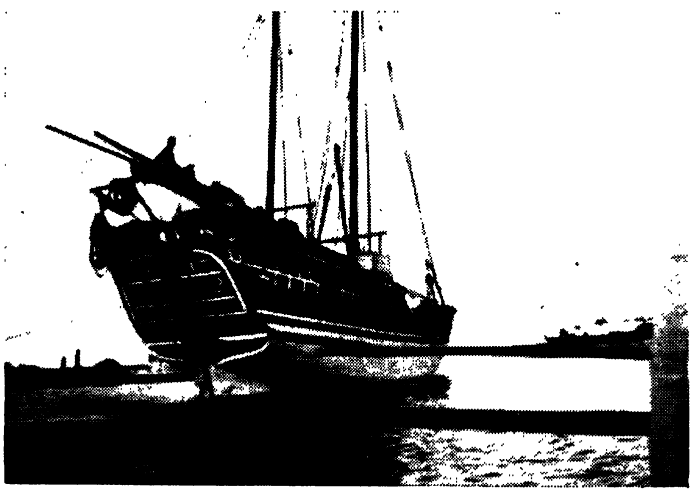

FIG. 71. Native sailing-ship (Sambūk).

vessels, which are able to beat into the wind, are being made at Wad Medani at the present time.

Donkeys

These animals are very useful for short carries. They will take a sack of grain or seed-cotton to market provided the distance does not exceed a few miles, but a man or a boy must walk alongside to balance the sack. Commercially they do not come into the picture for long carries, though their native owners often use them for carrying light loads when they are on the move from one place to another.

Provided cradles are attached to the saddles they can be very useful during building operations for carrying stone, bricks, rubble, sand, &c., for short distances. They are also commonly used for carrying water in canvas bags or in waterskins.

Sambūk (Native sailing-craft)

These are in common use for coastal traffic on the Red Sea. They ply between Port Sudan, Suākin, Trinkitāt, and Aqiq. The entire Tokar cotton crop has often been transported by them from Trinkitāt to Suākin

or Port Sudan. Though they have very little freeboard when loaded, losses of, or damage to, cargoes at sea have been remarkably light. In consequence insurance rates on Tokar cotton during its transport by this means are low.

Carts

The traditional form of transport in the Sudan for long carries is the pack-camel. The development of the country has been recent and synchronous with the development of the lorry, hence there has been no real need for animal-drawn vehicles; added to this there is a lack of wheelwrights and carpenters capable of devising and turning out satisfactory types of carts. In many ways this is a pity as it results in cash continually leaving the country in order to purchase lorries and fuel.

In the large towns carts drawn by horses, mules, and occasionally bulls or camels are used to a certain extent, but the carts themselves, with the exception of those used by Government services, are of poor design and construction and are only suitable for travelling short distances.

Head-carriage

In Equatoria Province this is the only form of transport other than lorries. It is not popular with the people; if commercial development depends on it, carries must be short.

Barges

Recently an experiment has been carried out in the Gezira on one of the irrigation canals with barges made from local sunt (*Acacia arabica* Willd.) timber and caulked with cotton. Hauling by camel was tried, but was not a great success; a tractor, however, has given promising results. There appear to be distinct possibilities of development of this form of transport in the Gezira for the transport of seed-cotton if suitable locks can be built at reasonable cost. The absence of locks necessitates extra handling which is inconvenient, expensive, and causes damage to the cotton packs.

The Economic Effect of Transport on Agricultural Development

The main adverse factor is distance: distance from markets and distances between the various productive areas.

As has been pointed out earlier in this chapter, the answer to this situation as regards exports is that they must be of high cash value compared with their weight. They must not only be capable of standing high freight charges in the Sudan, but also, in most cases, the high Suez Canal dues. A glance at the Annual Report of the Department of Economics and Trade for 1939 will show that in that year 63·3 per cent. of the total value of the country's exports was provided by ginned cotton. With the exception of gum arabic (13·3 per cent.), another high-priced product, no other commodity exceeded 4 per cent. except cotton-seed which stood at 4·4 per cent.

There is often an import into the Sudan of perishables such as fruit and

vegetables. The slowness of transport from Equatoria and Darfur and the paucity of cold-storage facilities prevent these provinces from supplying the rest of the country with its requirements of such commodities.

Acknowledgement

My grateful thanks are due to the General Manager, Sudan Railways, for the section of this chapter which deals with Rail and Steamer Rates, and also for checking and partially rewriting the sections entitled 'Ports, Railways, and Steamers'.

CHAPTER X

LAND TENURE IN AGRICULTURAL LAND IN THE SUDAN

By A. R. C. BOLTON, 4 N

INTRODUCTION

THIS chapter outlines the several modes of tenure of agricultural land, as distinct from 'Town land', now prevailing in the Sudan.

The settlement[1] of rights to land and the registration of title to those rights are provided for in the Sudan by the Land Settlement and Registration Ordinance, 1925, which superseded previous legislation on the subject. Prima facie all unregistered land is deemed to belong to the Government, but in practice the Government exercises its ownership as a trust for the people who have habitually exercised rights over it and has consistently refrained from interference with such rights, whether communal or individual, in unregistered land.

In the riverain and Gezira areas of the Northern Sudan the right to individual ownership has been persistently claimed and upheld as corresponding with the customs and views of the people. On the other hand, where land is cultivated at irregular intervals or is superabundant it is commonly recognized both by the people and the Government as held communally and it is administered by the authorities of the tribe, village, or other communal unit, the only right of the individual being his right as a member of such a unit to cultivate, cut wood, and so on in accordance with custom or as the authorities of the communal unit direct. Therefore in such areas as Kordofan and Darfur, where land is generally held communally, the policy of the Government has been to avoid registration of individual rights unless and until such rights are established beyond all doubt. Settlement of rights in agricultural land followed by registration has been undertaken very extensively in the Northern Province and the provinces of Khartoum and the Blue Nile, but outside these provinces the necessity for registration has seldom arisen.

For the sake of clarity it is necessary henceforward to treat the northern Sudan, which is Arabic-speaking for the most part and in which the Mohammedan Law applies, separately from the southern Sudan with its predominantly pagan population. In the northern Sudan land commissions and land registration have been invoked whenever the clash of the claims of individuals with each other or with Government claims has given rise to such a degree of uncertainty or such an amount of litigation as to make a general local settlement and registration desirable. In the southern Sudan, on the other hand, there has been no land registration and the position of the individual *vis-à-vis* the community is still defined by custom alone. The Nuba Hills, where the development of rain-grown cotton is forcing the pace in the direction of individual ownership in the

[1] Wherever the term 'settlement' is used in this chapter it means settlement of rights in land, followed by registration.

plains, are a half-way stage between north and south and will require special mention. The paragraphs in Part I of this chapter are descriptive only of the northern Sudan.

PART I. AGRICULTURAL LAND IN THE NORTHERN SUDAN

(i) *Forms of Ownership of Land classified*

The transition which is usual when a primitive community becomes sedentary is, by stages, from communal ownership of land by a tribe to ownership by a group, and finally to individual ownership. Examples of these exist in different parts of the Sudan. Such are tribal ownership of land by a nomad tribe, ownership of land by a village community in Kordofan, individual ownership of land on the river or in the Gezira.

Individual ownership of land is recognized in Mohammedan Law and the bias of the native mind is towards it. It derives from a right conferred by first clearing of land, followed by continuity of possession and regularity of cultivation. The validity of a claim to individual ownership depends also on whether custom requires that land should be inherited according to Mohammedan Law, and recognizes sale and purchase of the land itself. From the beginning the Government accepted the position that absolute individual ownership over land could be established according to native custom, but as early as 1905 the consent of Government to sales of land was required in order to check speculation and to prevent the creation of a landless class by the accumulation of large blocks of land in one man's ownership, and the Land Settlement Ordinance of 1905 stipulated, first, that 'waste, forest and unoccupied land shall be deemed to be the property of the Government until the contrary is proved'; secondly, that 'In the case of land which under the customary methods of cultivation is cultivable at irregular intervals, the fact that a person has cultivated for whatever period, shall not by itself give him the absolute ownership of the land'.

The general policy adopted in the course of land settlements of riverain land and the Gezira was to recognize claims based on continuous cultivation but not to recognize claims based only on ancient grants or on the cultivation by a claimant's ancestors of land subsequently abandoned.

The Government also recognized that ownership of land could be in the Government and registered to it subject to rights of cultivation and grazing of villagers as a body. Further, in areas where there was no land settlement the existence of tribal and village lands was formally recognized.

Private rights over land may, of course, exist in unsettled and unregistered as well as in settled and registered land. Land settlement and registration has merely determined rights. Therefore division of land into registered and unregistered is inadequate, and the following classification has latterly been preferred and will be adopted here:

(*a*) Government land subject to no rights.

(*b*) Government land subject to rights vested in a community, such as a tribe, section, or village, or sometimes in individuals.

(*c*) land individually owned.

Land of all these classes has been registered.

(ii) *Government Land subject to No Rights*

In the delta lands of Tokar and the Gash the Government has refused to recognize rights but has admitted that certain classes of people should be treated in a preferential manner.

Tokar was reoccupied before 1899. The first allotments of land were made to tribes and not to individuals. These early allotments were abused by powerful individuals for their own purposes, and in 1904 a Land Commission decided that land in the delta, where a good flood by the Baraka river may enable as much as 75,000 feddans[1] to be cultivated in a good year, was Government land not subject to tribal or private rights, but recommendations were made recognizing the original actual cultivators as a privileged class. Land is allotted annually by a Board, with preference to indigenous tribesmen in a unit called a 'dimin', which term comprises a large tribal holding scattered over the delta or a small individual holding. The policy now is to reduce the size of holdings and increase the number of cultivators. In the beginning an annual rental was collected, 'strangers' paying a higher rate than indigenous cultivators, but this ceased in 1926. Government now takes 20 per cent. of the money value of the cotton, which is the main crop, actually passing through Tokar market.

In the Gash Delta north of Kassala up to 85,000 feddans of land may be irrigated by the flood-waters of the Gash. Here areas called 'shaiōt' have been cultivated for generations by particular families or individuals. In 1906 a register of 'shaiōt' holders was made. Following a similar abuse to that which occurred at Tokar in 1918, the position was thus defined in a proclamation. The land was Government land. It could be allotted to registered holders of 'shaiōt', but the allotment could be revoked and cultivation rights in 'shaiōt' terminated. When an irrigation scheme was introduced in 1923 preference was given to registered holders of 'shaiōt'. Since 1927, when the Kassala Cotton Company which followed the previous Government practice relinquished its concession in the delta after three seasons, a 'Gash Board' representing the Government has managed the area. Land is allotted rent-free on a system of annual tenancies to cultivators, allotment being on a tribal basis with preference to registered holders of 'shaiōt' and members of tribes which had *exercised* cultivation rights. Indigenous tribesmen hold 70 per cent. of the tenancies. A tenant receives 50 per cent. of the net proceeds from the sale of the cotton crop and is able to grow a grain crop free of tax.

The ownership of river land in the riverain provinces has been extensively settled and registered. Riverland comprises 'sāqiya' land, that is land irrigable by water from the river or cultivable by well water-wheel, back land which is land incapable of cultivation by water-wheel but suitable for date-trees, and 'selūka'[2] land, or land irrigated by natural river flood.

(iii) *Government Land subject to Rights vested in a Community*

This heading covers tribal lands, the bare ownership of which land is in the Government.

[1] 1 feddan = 1·038 acres.

[2] The term 'selūka' includes all land flooded at high Nile, namely the sloping bank called 'gerf', an adjoining piece in the river-bed, and an isolated island.

The large areas occupied by nomadic or semi-nomadic tribes in the provinces of Kassala, Kordofan, and Darfur are tribal lands. The Bēga tribes in the Red Sea Hills, the Kabābish and Kawahla of northern Kordofan and the Baggāra tribes of southern Darfur have almost unrestricted enjoyment of a large area of territory known as the tribal 'dar'.

In the greater part of Kordofān and Darfur, in Gedaref and Singa districts, and in that part of the Blue Nile which lies across the White Nile, land (other than riverain) is still held communally and, since the inhabitants are mainly sedentary, the unit is the village.

The Kordofan village is typical of communal holdings in areas where there is a light sandy soil requiring frequent changing of plots suitable for gum-trees. Within the village lands each villager has the right to cultivate. If he leaves the village the land occupied by him is allotted to someone else. There is no inheritance according to Mohammedan Law. Land in excess of the requirements of the village may be allotted by the sheikh to strangers. The area allotted to a man is supposed to be no more than he can work ('kifayat yed'). Gum gardens fall into two classes, those within the boundaries of a village and those outside it. A villager has the right to tap the trees which spring up on the plot of ground which he has abandoned because it has become exhausted after several years' intensive cultivation. A short absence does not deprive him of the right to tap these trees. It is not unknown for a villager to pay a due to the sheikh for the privilege of tapping, but a stranger is required to do so. Gum gardens outside the boundaries of a village are regarded by custom to be at the disposal of the tribal chief who as the agent of Government is entitled to collect these dues from tappers. In Singa and Gedāref districts it was necessary to introduce Government control to stop unauthorized collection of rent and subletting.

It is customary for any member of a tribe to have the right to graze his animals at will over the tribal land of his tribe provided they cause no damage to cultivation or to gum gardens. The responsibility for keeping animals out of cultivation and gardens is on the herdsman owing to the impossibility of making adequate fences.

Grazing boundaries exist between tribes in cases where ill feeling has made them necessary on administrative grounds. Similarly grazing boundaries may exist between sub-sections of a tribe or adjoining villages, but they are an exception to the common practice.

Strangers are required to obtain permission to graze their herds. There are cases where such permission has become permanent subject to conditions, otherwise permission may depend on the amount of grazing available.

It is customary for the member of a tribe to have the use of standing water whenever it is available, and it is contrary to a custom backed by the Mohammedan religion to deny its use to anyone, but the right to open up a well in a well-field is often restricted to the particular group living in the vicinity or normally grazing in the area. Where the supply of water is short the right is jealously guarded. While a stranger passing with a few animals is never denied water, seasonal watering of herds of strangers is the subject of agreement between the parties concerned.

The need to safeguard the rights of the group against encroachment by the individual has been exercising the province authorities. The native authority has power to settle land cases according to tribal custom. If the dispute is between members of the tribe no question of ownership is involved since the tribesman's right is to the use of the land.

(iv) *Land individually owned*

Individual ownership of land was established in the course of settlements of riverain land between Halfa and Kosti and of the rainland of the Gezira.

'Sāqiya' land is for the most part held in private ownership in small holdings. Large areas of 'selūka' land have been settled, and much of it adjudged to individuals. 'Selūka' land of the White Nile, which unlike 'selūka' land in the main Nile and the Blue Nile is permanent and may have no 'sāqiya' land behind it, was settled early and periodically revised. The last revision in 1936 formed a basis for the payment of compensation on account of flooding by the Jebel Aulia Dam.

North of Khartoum 'selūka' is less permanent and the behaviour of the river leads to a variety of practices. For the most part the sloping bank and the adjoining piece in the river-bed belong to the 'owner' of the 'sāqiya' land above, but in the Sukkot area of Halfa district the 'selūka' owners and 'sāqiya' owners are distinct, as is the case in the Monasir country in Berber district. In some cases the high land has been sold without the sloping bank ('gerf') pertaining to it, but native opinion is inimical to the severance of 'sāqiya' and 'selūka' land since custom divides the river into rectangular blocks divided in the middle of the river by an imaginary boundary called a 'mirin' which lies in the direction of the flow of the river. The other boundary of the block is at right angles to the river and is called a 'fasil'.

An unusual tenure exists in the Monasir country. Ownership of the land is vested in one person, Sid el Asl, whereas the right to cultivate without rent belongs to another, Sid el Miswaq. The only benefit received by the former is a share in date palms.

Individual ownership in intensively cultivated rainlands was recognized in the Gezira, as documents of title dating from the Fung kings were in existence and private ownership was accepted by early land Commissions and Civil Courts. By 1927 the whole of the Gezira had been settled. When a large part of the Gezira was required for development by the Sudan Plantations Syndicate the course adopted was not to expropriate the registered owners but to provide for the compulsory hiring of land by the Government for a period not exceeding 40 years on payment of an annual rent of P.T. 10 (2*s.*) per acre. The Gezira Land Ordinance of 1927 which empowered this measure also provided for the purchase, on payment of compensation not exceeding £E.1 a feddan, of land required for permanent works or for seed or research farms. The owners of land which was thus rented or acquired by the Government were given preference in the allotment of tenancies.[1] The Government has made substantial purchases of land yearly, buying in the open market.

[1] Details of the Gezira Scheme are given in a separate chapter.

There exist instances of unregistered land held in individual ownership. They are the Atmur lands in Berber and Shendi districts and the Kheiran in Kordofan.

In Berber and Shendi districts there are wadis (watercourses) which are watered every few years. They are considered by the people to be held individually, and the land is treated as river land in that sales and mortgages take place, it can be leased to strangers, and there is the same terminology. The fact that the Government likes to treat the land as tribal land has not deterred the people from recognizing individual ownership. A similar state of affairs exists in the Abu Deleig wadis occupied by Batachīn and Jaalin. In Shukriya wadis the ownership of the tribe is still accepted by the people.

The Kheiran are the only exception to the rule of communal or village ownership in Kordofan Province. They are a series of khors (troughs) in which water is so near to the surface that cultivation is by water-wheel or lift. The land was once tribal land of the Dar Hamid tribe, but strangers were introduced under the Turkish Government. They paid dues to Dar Hamid tribesmen until swept away by the Mahdi. When the strangers' descendants returned, both they and the descendants of the lessors claimed individual rights. Notwithstanding the principle that ownership is vested in the tribe, land actually passes according to Mohammedan laws of inheritance, and individual ownership is claimed with great tenacity.

(v) *Claims by Overlords*

A difficulty met in certain land settlements was the claims of overlords. Government insisted on the principle that waste and unoccupied land was prima facie the property of Government and overlords' claims were overridden, but a peculiar position exists in some places where there has been no land settlement and registration, owing to certain families having in the past acquired sovereign rights derived from their belonging to a ruling dynasty.

In Rufaa district the tribal heads of the Shukriya claimed the right of ownership over tribal rain land. An arrangement was made in 1903 whereby natives could buy their land from the ruling Abu Sin family, but it was not applied to one whole 'khut' (tribal division). A settlement in 1935 decided that the land was tribally owned. Some lands which had been awarded to the ruling family by an early Civil Court decision were made over to the cultivators on their commuting by payment of a fixed sum the dues which they had been paying to the 'landlord'.

But 'overlords' rights claimed in Singa district have not been upset. Early commissions recommended recognition of a system of hereditary landlords owning large areas. Subsequently it was accepted that the rights exercised were rights to sovereign dues and not of private ownership, but the collection of due called 'khums' (a fifth) continues and is officially recognized, the view being that the right to collect dues does not constitute full ownership and is not transferable but is vested in the head of the ruling family.

(vi) *Acquisition of Land by Government*

As early as 1903 an enactment was made enabling the Government to acquire land by expropriating all rights. The existing law is the Land Acquisition Ordinance, 1930, which enables the Governor-General to acquire land for a public purpose on payment of compensation. Land can be acquired by the Government outright or occupied temporarily for a period not exceeding 15 years by the Government or suitable persons, or acquired permanently by Government for disposal to private persons for development in the public interest. Before expropriation takes place, land which is not registered has to be settled and registered with a view to ascertaining the rights which have to be expropriated and assessed for compensation.

This ordinance has been frequently invoked to create Central and Provincial Forest Reserves. A Central Reserve is administered by the Chief Conservator of Forests and is free of all rights other than the public's right to use specified roads and watering-places. A Provincial Reserve is administered by the Governor of a province, subject to rights which were not expropriated because they were not considered prejudicial to the reserve.

Expropriation of rights has taken place near Shendi in 'karū' land, that is land lying behind 'sāqiya' land, cultivable only when there is an exceptionally high Nile or when good rains cause watercourses to flow. This land when it is lower than 'sāqiya' land is called basin land. The Shendi 'karū' lands had been adjudged to Government subject to cultivation rights by an old settlement. These rights were preventing development, and in order to use the basins to the best advantage 17,000-odd acres were expropriated in 1938. The land was disposed of on a 99 years' lease, as far as possible to the expropriated right owners, at a nominal annual rent of 1 m/m. a feddan, with provision for good husbandry.

Similar land in Khartoum Province, called 'bugr', which had been registered to Government subject to rights of cultivation and grazing, has been likewise expropriated when it has been required for inclusion in private pump-schemes. The pump owner was called on to pay the cost of expropriation by way of a premium and the land was leased to him at a low rental. A clause in his lease stipulates that expropriated right owners must be given preference in the opportunity to participate in the pump-scheme.

The raising of the level of the White Nile consequent on the construction of the Jebel Aulia Dam for storage of water for Egypt deprived the inhabitants of a large part of their agricultural lands and of their chief means of livelihood. Therefore Alternative Livelihood Schemes were devised, one at Abd el Māgid in the Gezira and at four pumping-stations on the White Nile. All the land required was expropriated. The schemes, so far comprising about 60,000 feddans, closely resemble the Gezira Scheme in that holdings are allotted on a profit-sharing basis.

The land which it was deemed would be submerged or damaged owing to the construction of the Jebel Aulia Dam was assessed for compensation, but the registered owners were not deprived of their title. A similar state

of affairs exists in Halfa district, where registered owners lost the use of their land on account of the heightening of the Assouan Dam in Egypt.

There are only a few instances in which the title carries any advantage, and compensation was assessed on the assumption that the use of the land had gone for ever.

(vii) *Disposal of Land by Government*

From time to time Government disposes of Government land which is entirely free from any private rights. It normally disposes only of land after registration to itself, but this was not always the case.

There existed in the Northern Province a number of schemes for the disposal on lease or freehold, usually after a short probationary lease, of riverain land of several types, some of which was not registered. The schemes embraced 'sāqiya' land, back land, and 'selūka' land. Private ownership of basin land irrigated by diversion of flood-water into a basin was not permitted. In Halfa and Dongola districts the separate sale of 'sāqiya' land and the adjoining 'selūka' land (called 'gerf') was not allowed. The disposal of the freehold of Government agricultural land of all kinds has now been abandoned, but land already disposed of freehold remains with its owners.

In 1942 a scheme was put into force to encourage date culture and fruit farming. It provides for the disposal of 'sāqiya' land and back land on a 99 years' lease after a preliminary 5 years' lease containing a good husbandry clause. The annual rent is 10 m/m.s a feddan plus land tax. The scheme is still in its experimental stage. Allotment of 'selūka' land on a short-term lease of 1 or 3 years continues. 'Sāqiya' land which is not allotted under the scheme is leased annually.

In Khartoum Province registered Government land, not required for inclusion in a pump-scheme, is allotted on an annual tenancy at the following rates: 'sāqiya' land, P.T. 10 a feddan; 'selūka' land, three times the land tax; rain land, one-fifth of the crop tax ('ushūr') which is itself one-tenth of the total yield. In the Blue Nile Provinces river lands are rented from Government on payment of one-quarter of the land tax and rain land at one-half the 'ushūr', or one-fifth the 'ushūr' in the areas of Manāgil and Sennar.

When Government land is made available for a private pump-scheme, the pump owner is given a lease the length of which depends on the term of the pump licence, with which it is coterminous. The licence varies with the size of the pump, the maximum period being 15 years in the case of a pump having a suction pipe of more than 10 in. diameter.[1]

In Government pump-schemes in the Northern Province land is leased to tenants on a yearly lease. The tenant pays a water rate and a nominal rent of 1 m/m. a feddan. He takes the whole of the crop except in the case of cotton which is shared equally by Government and tenant.

On the White Nile, in the area of the old White Nile Province, since 1935 the native administrations of Dar Hassania and Dar Baggara and

[1] Nile Pumps Control Ordinance and Regulations, 1935.

two minor administrations (Shawal and Aba) are empowered to manage on behalf of Government all registered Government rain and river land. It is allotted to bona-fide cultivators by annual cultivation permits on payment of P.T. 5.

At Zeidab a concession area of 15,233 acres is held in freehold by the Sudan Plantations Syndicate. The original concession was to a Mr. Leigh Hunt, from whom it was acquired by the Syndicate. Some extensions were subsequently made to the Syndicate's freehold, the last in 1936.

(viii) *Disposal of Land by Individuals*

The transfer of rights over land, both registered and unregistered, between individuals is regulated by the Native Disposition of Lands Restriction Ordinance, 1918, which directs that the approval of the Governor shall be obtained for any form of disposal of land. The disposal of registered land between natives is facilitated by an Ordinance of 1922[1] enabling Governors to delegate their powers to, *inter alia*, Native Authorities or Native Courts in respect of transactions between natives of the Sudan who are also inhabitants of the province.

The Pre-emption Ordinance 1938 gives co-owners of undivided shares and owners of irrigated land adjoining land up for sale in the same irrigation unit a preferential right to the purchase of another undivided share or adjoining land, as the case may be.

PART II. AGRICULTURAL LAND IN THE SOUTHERN SUDAN

(i) *Tribal Land in Equatoria and the Upper Nile Provinces*

It has been pointed out that the settlement of rights in agricultural land, followed by registration, has not been extended to the Provinces of Equatoria and the Upper Nile. This is, first, because there is plenty of land; secondly, because the inhabitants are for the most part in a stage of development when land is held in common by a tribe or group and an individual has no right except as a member of such tribe or group. Thirdly, the inhabitants are pagans and unaffected by the recognition given to individual ownership of land by Mohammedan Law.

For these reasons the law that land in the southern Sudan, because it is all unsettled and unregistered, is held by the Government in trust for the people who habitually exercise rights over it, has not had to be propounded, nor has the question of Government ownership been put to any test.

There is among the Nilotic tribes occupying the greater part of the Upper Nile a different use of land according as they are sedentary or semi-nomadic in their habits.

The Shilluk are sedentary, occupying long stretches of land on the fringes of the White Nile. Their country is divided into 100 settlements. The descendants of the original grantees of the settlements are considered owners of land and carry the title 'dyil'. Even when dispossessed of the chieftainship a 'dyil' lineage remains the owner of the soil. Within

[1] The Native Disposition of Lands Restriction Ordinance, 1922.

a settlement each lineage has its hamlet. The 'dyil's' association with the land is ritual, and the enjoyment of land by the individual member of a hamlet is not restricted in the interests of the 'dyil'.

The Nuer, and for the most part the Dinka, are cattle people. Their social life is wrapped up in the life of their herds. They do not occupy fringes of land along the river but much larger areas. Each tribe is an economic unit with its own pastures and water. Each section has a well-defined area over which it has grazing and cultivating rights. Boundaries exist between the areas of sections and sub-sections. Among the Nuer boundaries exist also between families. The area allotted is large as it must provide sufficient grazing for their animals, but land is plentiful and disputes are rare. Rights extend to grass and cultivation only; anyone can hunt or collect gum or even cut down trees. If a fire spreads there is no claim against the person who started it. Fishing rights go with land, and a stream is divided into sections.

A feature peculiar to the Nuer, who are the dominant tribe in an area which was once occupied by Dinka, is that in each tribal area there are clan-owners called 'diel'. They are a dominant element, but the tribe owns all the country, its fishing-pools, and even the village sites.

The Anuak, who are a tribe of the Upper Nile Province belonging to the Shilluk-Luo group of the Nilotic peoples, live in independent village communities. There is in each village a functionary called 'father of the land' who is not always the headman of the village. He is a direct descendant of the original occupier of the land where the village and its cultivation are situated. Though referred to also as 'owner of the land', his functions are connected with the fruits of the earth. By distribution of seed and regulating sowing, with accompanying ritual, he makes the soil fertile.

It is safe to say of the vast Equatoria Province, where the amount of land is greatly in excess of the needs of a sparse population, that there is no individual ownership of land since the individual is regarded primarily as a member of his clan which owns the land. Space does not permit of more than a summary of the features of this clan ownership which are common to several tribal groups.

Clan lands are well defined by natural boundaries. Land may be purchased by one clan from a neighbouring clan. The head of the clan is the authority in land. Strangers can cultivate only with his permission. An individual has the usage of the plot he cultivates. If a plot is abandoned it reverts to the clan. Cultivation rights pass from father to son with the widow often participating. Grazing and watering rights inside the clan land are free to all its members. A river is divided between the clans on its banks.

In most tribes of the Nilo-Hamitic group there is an earth-chief who resembles the 'father of the land' found in an Anuak village. The earth-chief's duty is to allocate clan land and to ensure its fertility.

Though they may take dues from those who cultivate, as happens in the Latuka group, they do not claim to exercise any owner's rights, and no problem of 'overlords' such as exists in the Rufaa and Fung Districts of the north is met with in the southern Provinces.

(ii) *Land Tenure in the Nuba Hills of Kordofan*

The recent research work of Dr. S. F. Nadel into the economic life of the Nuba has provided the explanation of the paradoxical state of affairs in which a primitive people who are in a stage when land would normally be expected to be held in common have individual ownership of land, notwithstanding their strong tribal organization.

The Nuba live in mountainous or rocky country. Their descent into the plains in search of land is a recent development due to the new security which was lacking before the present Government. They attach great importance to farming. Their farms are of three kinds, 'house-farms', 'hill-side farms', and 'far-farms' in the plains. The first two are terraced, the house-farm being near the home is regularly manured and permanently cultivated. It is the fruit of the labour of generations. The nearer a farm is to the home the more valuable it is owing to better security and time saved. There was always plenty of land farther from the village or hill, but its remoteness meant wasting precious working hours. In all these circumstances it is not surprising that a system of individual ownership developed.

Every tract of land that is or has been under cultivation in the Nuba Hills is individually owned. Individual right is established by putting land under cultivation, and holdings, though they may not be worked for several generations, do not revert to the common store of land. Land is acquired by clearing, inheritance, purchase, and lease. Everywhere house-farms are bought and sold, the price depending on whether land is scarce. Strangers, however, have to pay inflated prices. Borrowing of land is a general practice.

The communal units among the Nuba are the village, hill-community, and tribe. Only individual holdings are marked by boundaries. A village does not claim a separate tract of land but shares in the land of the hill-community. The land of the hill-community has no artificial boundaries. It is determined by geography and space. Tribal areas are not bounded if there is sufficient space between tribes. There is no feeling against individuals crossing a tribal boundary, and a liberal attitude is adopted towards strangers. In no Nuba tribe is there a special land authority.

This happy state of affairs is a relic of the days when there was land in plenty and before far-farms were opened up in the plains. Now that growing of cotton has led to much more extensive cultivation and plain cultivation is safe and attractive, clashes over land are becoming more frequent. The day is approaching when there will be clashes between corporate groups. The system of Nuba tenure will have to be adapted to changing conditions. The Chief's Court is the new machinery for the settlement of land cases. On it lies part of the responsibility for proper adjustment during the period of transition. The research work of Dr. Nadel was for the guidance of the Government with whom lies the ultimate responsibility for the complex problem of the Nuba Hills.

CHAPTER XI

REVENUE FROM LAND AND CROPS

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I. TAXATION—HISTORICAL NOTE

THE Sudan had no unity and no history until the second decade of the nineteenth century and very little need, or indeed can, be said about taxation prior to the time Ismail Pasha, son of Mohammed Ali, set out to conquer the Sudan and make it a part of Egypt. Thereby was achieved some kind of unification of a country which was vaguely described at the time as extending from Wadi Halfa to the Equator and from the Sahara to the Red Sea. But what Mohammed Ali failed to introduce were justice and order into his newly founded domain; misgovernment ruled, and rapacious underlings covered the land. Gordon, immediately he landed at Khartoum North towards the end of this régime in February 1884, made a bonfire of the tax-gatherers' books, and his action is sufficient indication either of the system of taxation in force or of the methods of assessment and collection at the time.

It was under the Khalifa's rule, which followed Gordon's death in 1885, that some definite progress towards unified taxation was made. A tithe on grain and 'zakāt',[1] on camels, cattle, property, and money were collected. Land was taken over and put out to lease. But tax collectors paid enormous rates for their appointments, which were well worth what was paid for them, and the system suffered accordingly.

When the Sudan was reoccupied in 1898 the first and most essential problem which engaged the serious consideration of the newly set-up government was the taxation of the people. Light and simple taxation, adapted to the special conditions of the Sudanese and their mode of life, was gradually introduced as a tentative and experimental measure. No avoidable innovation based on Western ideas was introduced, and it was the list of taxes collected under the Dervish rule that provided the best guide to the new administration. Cruelly though those taxes had been extorted from the people, it was found that they were based on principles generally recognized in all Moslem countries and were eminently suitable to the country.

Land tax, date tax, animal tax, 'ushūr' (tenth or tithe), and tribute found

[1] According to Mohammedan theory, the revenue of a Mohammedan State falls into two classes—religious and secular revenues. The former is derived from the Moslems and is chiefly made up of the so-called 'zakāt' taxes, of which there are, for practical purposes, three kinds—'zakāt' of flocks and herds, 'zakāt' of commercial capital, and 'zakāt' of agricultural produce (or tithe). The latter, on the other hand, is collected from non-Moslems and consists principally in the 'gizya', the 'kharāg', and the fifths levied on spoils of war, mines, and treasure trove, the 'gizya' being a poll tax on male non-Moslem subjects and the 'kharāg' being a tax on land in accordance with its area or produce.

early places in the taxation structure. There have been periodic examinations of the general question of taxation with the view of effecting such modifications as experience dictated and of abolishing taxes which caused the maximum amount of loss and annoyance, particularly among the poorer classes; but it is interesting to note that the traditional taxes mentioned above have withstood the test of time; and that direct taxes related to crops or animals, or both, remain a part of the taxation system of the Sudan.

II. Direct Taxes

The following are detailed notes on current taxes wholly related to land or crops:

(i) *Land Tax*

Imposed under the Taxation of Land and Date Trees Ordinance, 1925.

This tax was adopted immediately after the reconquest as a cultivation tax on land other than land dependent on rainfall and was at first confined to that part of the Northern Sudan then known as Dongola Province. It was later introduced in other provinces.

To-day land tax is applied in two ways:

(*a*) First, as a tax on the potential value of the land without regard to what crops may or may not have been produced. This system implies that accurate maps and a registration of ownership of the land exist. When this is the case the land is assessed as having a taxation value of so much a feddan, and the ordinance provides a scale of rates, in 10 P.T. stages, from 10 P.T. to 100 P.T. a feddan.

(*b*) Secondly, as a corresponding tax to 'ushūr' (see sub-paragraph iii) on rain-land, by assessing the actual gross value of the crops produced and assuming that the tax is a fixed percentage of such gross value, the fixed percentage decreasing as the expenditure necessary to each form of cultivation increases.

The second method is gradually becoming the recognized method, and in actual practice land tax in the Sudan is developing into a crop tax assessed at a percentage of local value.

(ii) *Date Tax*

Imposed under the Taxation of Land and Date Trees Ordinance, 1925.

This tax, which is now applicable only in the Northern Province, imposes a maximum rate of 2 P.T. per annum on the owner or co-owners of every male date-tree which has reached the flowering stage and of every female tree which has begun to bear fruit.

In practice the rate of date tax is assessed at 10 per cent. of the value of the yield, subject to the prescribed maximum, and the trees liable to tax are based on a count carried out every 5 years by a specially appointed board. The tax is usually collected during the last quarter of the year when the crop is on the market.

(iii) *Ushūr*

Imposed under the Taxation of Rain Lands (Ushūr) Ordinance, 1924.

'Ushūr' ('tithe') is a tax on crops grown on land watered periodically by

rain or river on which no land tax or rent in lieu of land tax is levied. It originated from the Moslem 'zakāt' and amounts, as its name implies, to one-tenth of the crop on which it is imposed.

The tax is collected at approved rates per 'ardeb'. The approved rates are fixed by the Financial Secretary, in consultation with each Governor, with due regard to the trend of local market values each season and for each kind of crop. They vary not only as between provinces but also as between districts, the proximity of the bigger centres of population or the railway and other local conditions being considerations to be borne in mind in addition to market values.

Assessment is laborious, entailing as it does inspection of all ripening crops by assessment boards comprised of selected native authorities, who estimate areas and yields and record the figures on lists against the names of the cultivators. The individual crop assessments provided by these lists are translated by district headquarters into cash assessments by application of the approved rates. The tax is then collected in money, it being lawful, however, for the Governor, with the approval of the Financial Secretary but only for some public purpose or public necessity, to direct with respect to his province, or any area in his province, that a part or the whole of the 'ushūr' shall be made in kind.

Owing to the variation in rainfall in different localities from year to year and other climatic conditions which affect the crops during the period of their growth, the revenue from this tax is always a fluctuating one.

During the 7 years 1936 to 1942 inclusive land tax, date tax, and 'ushūr' produced an average annual revenue of £E.92,219, of which £E.20,084 came from land tax, £E.21,290 from date tax, and £E.50,845 from 'ushūr'. Land tax during these 7 years varied from £E.15,201 in 1938 to £E.24,244 in 1942; date tax varied but little, while 'ushūr' varied from £E.33,980 in 1941 to £E.62,924 in 1938.

The following table shows how these results were spread over the eight provinces:

Province	*Land tax* £E.	*Date tax* £E.	*'Ushūr'* £E.
Blue Nile	4,980	..	33,674
Darfur	..	..	..
Equatoria	..	..	..
Kassala	37	..	13,796
Khartoum	2,435	..	149
Kordofan	132	..	2,799
Northern	12,500	21,290	427
Upper Nile	..	..	..
Total	20,084	21,290	50,845

Two other current taxes must also be mentioned under the head of direct taxation:

(iv) *Poll Tax*

Imposed under the Hut and Poll Tax Ordinance, 1925.

This tax is imposed at flat rates per adult male. It is almost entirely restricted to the Southern Sudan, and was introduced in lieu of cultivation

and animal taxes as being more suitable to the primitive conditions of the people concerned.

(v) *Tribute*

Imposed under the Tribute Ordinance, 1925.

Prior to 1934 tribute was paid only in lightly administered districts in order to maintain the importance and sense of responsibility of the heads of backward tribes. Since that date, however, tribute, archaic though the name sounds, has been used to assimilate 'ushūr', animal tax, and poll tax, or a combination of these, on a collective basis. In Kordofan and certain districts of Kassala care is taken to ensure that the heads of taxation are retained locally; animal tax lists are computed and crop assessments are made out annually, and these are utilized in estimating the taxable capacity of the districts affected.

As tribute and poll tax are not, however, related wholly to land or crops they have not been taken into account in assessing the Sudan's direct taxation from this source.

The possibility of rolling up all direct native taxation, namely 'ushūr', animal, land and date taxes, tribute, and possibly also poll tax under one head and under one ordinance is a matter which has received active consideration, but one which has had to be postponed.

III. Direct Taxes and Local Administration

Ever since the reoccupation of the Sudan took place the maintenance of taxation at a low figure has always been the aim of the administrators.

The policy was stated at the outset and is now established, and since 1899 the Sudan system of taxation has developed in company with the growth and consolidation of the country. Direct taxes related to crops remain a part of the system. Increased dependence, in order to meet the higher cost of administration, has had to be placed upon indirect taxation, much of which is, in its turn, dependent upon what the country produces, Reference to some of these indirect taxes will be made later, but before any note on direct native taxes as applied in the Sudan is complete something must be said about the social aims of such taxes as well as about their revenue aspects.

Land tax, date tax, and 'ushūr' during the 7 years reviewed produced but 1·4 per cent. of the Sudan Government's total annual budgetary revenue, and would thus at a glance appear to be inconsequential except perhaps as an illustration of the carrying out of the policy of moderation in face, sometimes, of strong arguments for departing from it.

These direct taxes, however, play quite an important part in the administration of the country.

Over the last decade considerable progress has been achieved, in conformity with the Government's policy of devolution to native authorities, in decentralizing upon local administrations an increasing financial responsibility for those matters which are preponderantly of local importance. Twelve independent budgets as an integral part of the machinery of local administration have been established. More will follow.

Date tax, as has been pointed out, is collected only in Northern Province

where no local authorities with separate budgets have as yet been constituted. The following table, however, illustrates the part these local administrations played over the 7 years 1936–42 in the collection of the land tax and 'ushūr':

	Land tax collected by		*'Ushūr' collected by*	
Year	*Provinces* £E.	*Local administrations* £E.	*Provinces* £E.	*Local administrations* £E.
1936	20,411	746	37,835	19,217
1937	19,662	1,994	34,647	19,671
1938	14,804	397	40,199	22,725
1939	22,169	1,634	20,841	18,131
1940	14,876	1,733	34,186	22,763
1941	17,011	909	18,255	15,725
1942	22,898	1,346	34,223	17,497

During the 7 years reviewed above land tax and 'ushūr' provided the administrations with over 17 per cent. of their total gross revenue, and in turn the administrations contributed an average of £E.60,800 a year to the Central Government. These and other direct taxes are, in fact, an important part in the essential foundations to the structure of local financial administration and, if only as such, are of fundamental importance.

IV. Indirect Taxes

(i) *Royalties*

Royalties on any produce of the Sudan, or of any part of it, may be imposed under the Royalties Ordinance, 1939, and are at present levied upon gum, tobacco, lawfully grown in the Sudan, 'dōm' palm fruits, and timber, charcoal, and firewood.

Of these gum is the most important from the revenue point of view, the rates of royalty at present in force being:

	Rate of royalty
Bleached gum	£E.13.000 m/m.s per metric ton
'Hashab' gum	£E.10.100 m/m.s ,, ,,
'Talh', other gum, and gum dust (other than bleached gum)	£E.1.000 m/m.s ,, ,,

The rate on 'dōm' palm fruits is 10 m/m.s per kantar of 100 rotls (or 2·25 m/m.s per 10 kilogrammes).

Royalties on these two products are levied and paid in cash upon export.

Tobacco lawfully grown in the Sudan is subject to a royalty of 50 per cent. *ad valorem* which is collected in the market through which such tobacco is bound to pass.

No royalty is levied on timber:

(*a*) when it originates from a central or provincial forest reserve;

(*b*) when exempted by the Governor as being timber intended for use, otherwise than by way of trade, in the construction of 'sāqiya', agricultural implements, houses for occupation of cultivators, or for public purposes such as the building of mosques, schools, and the like;

(c) when grown in a private plantation and exempted by the Governor with the consent of the Financial Secretary.

The ordinary rates imposed on timber other than that so exempt vary according to variety and size, ranging from 25 P.T. per large 'kutla' (a piece 42 in. or more in mid girth) of mahogany, 'duruba', 'bu', or 'pai' to 2 P.T. per 'rassas' (a piece less than 15 in. in mid girth) of sunt, 'salag', 'zan', or 'sidr'. Special rates are prescribed for timber for boat-building based upon the boat's capacity, and there is a fixed rate per 'asāra' for oil-presses.

Royalty is imposed upon all charcoal and firewood (except that originating from a central or provincial forest reserve) intended for export or for use in the way of trade anywhere in the Sudan or, in the case of firewood, for domestic use in the Khartoum municipal area, Wad Medani, and, in the case of charcoal, for domestic use in the provinces of Khartoum and the Blue Nile.

The rate on charcoal is 2 P.T. per kantar of 100 rotls and on firewood 1 P.T. per kantar of 100 rotls or 10 P.T. per cubic metre, but special methods of assessment, for example according to a boat's or an animal's carrying capacity, in lieu of assessment by actual weight, are permitted.

Royalties collected during the 7 years 1936–42 were:

Year	*Gum* £E.	*Other articles* £E.
1936	212,520	23,071
1937	173,557	33,587
1938	218,888	26,086
1939	210,371	25,853
1940	196,394	45,996
1941	171,469	37,153
1942	129,170	43,891

(ii) *Customs*

All Sudan produce, except for samples of the products of the soil of the country not exceeding £E.10 in value, is subject to a duty of 1 per cent. *ad valorem.*

The export duty collected on Sudan produce during the 7 years 1936–42 exceeded £E.55,000 a year.

V. Commercial Undertakings

The cultivation of cotton on Government lands, or lands rented by the Government for the purpose, is a form of industry which has been created under the present Government. Great assistance is rendered to the cultivators who can afford (and the Government are justified in demanding) a levy at a higher rate than the standards provided by the direct taxation methods already explained. Such a levy is properly regarded as partly rent, partly payment for water and services rendered, and partly tax, and is related to the value of the cotton produced. The industry includes:

(i) *The Gezira Irrigation Scheme*

This scheme was envisaged in the very early days of the reoccupation. Systematic study of the possibilities of the prospects for the successful cultivation of cotton grown under artificial irrigation in the Gezira dates

from 1904. But it was not until 1911 that the first experimental pump-scheme was started. A further area was canalized by pump in 1913, followed by two more schemes in 1921 and 1923.

In the early experimental days the tenants were charged a fixed rate for the supply of the water and the project was managed by the Sudan Plantations Syndicate; but when it became clear in 1913 that a bigger project could be considered, a more permanent basis for co-operation between the Government and the Syndicate and the native cultivators was sought, with the result that a profit-sharing arrangement was introduced. The Government having supplied the capital for the major canalization became responsible for the financing and running of the pumps. The Syndicate became responsible for minor canalization, for management of the whole enterprise, and for financing the tenants. The tenants themselves supplied the labour as cultivators. The cotton crop was divided into portions of 35 per cent. to the Government, 25 per cent. to the Syndicate, and 40 per cent. to the tenants, while other crops (grain and fodder) all went to the tenant free of any deduction or tax. The results of the introduction of this arrangement have been very far-reaching not only in the Gezira but elsewhere in the Sudan.

The dam across the Blue Nile at Sennar was completed in 1925 and irrigation by gravity took the place of irrigation by pumps. The first season saw 240,000 feddans, of which 80,000 feddans were watered and sown with cotton, allotted to tenants. The scheme to-day comprises a gross area of some 873,000 feddans, of which about a quarter is grown with cotton annually.

The Sudan Plantations Syndicate remained as managers on the partnership basis set out above. In 1926, when the area of their concession was substantially increased, a new agreement with them was concluded whereby their share fell progressively to 20 per cent. and the Government's share correspondingly rose to 40 per cent. This division of shares as between the Government and the Syndicate was, however, upset when, in 1929, the latter's share in respect of an extension of area of about 100,000 feddans was raised to 22½ per cent. subject to a decrease to 20 per cent. or an increase to 25 per cent., if the actual results of the extension were much above or below basic expectation.

The division of shares between the Government and the management was further complicated when, in 1928, an extension of the scheme was entrusted to the Kassala Cotton Company in substitution of a concession to the company in the Gash Delta. Special circumstances demanded a larger share to the company in the proceeds of the cotton crop, which was fixed at 30 per cent. subject to variation in certain eventualities.

Throughout the scheme the division of the proceeds of the cotton crop is now approximately as follows:

To the Government . .	38 per cent.
" " Companies . .	22 " "
" " Tenants . .	40 " "

During the 7 years 1936–42 the Government's share on the above basis was as follows:

Year	£E.
1936	863,453
1937	1,468,199
1938	801,207
1939	1,014,227
1940	681,567
1941	1,418,548
1942	1,369,829
Average	1,088,147

(ii) *White Nile Alternative Livelihood Schemes*

These schemes were established to meet the alternative livelihood requirements of the riverain people affected by the construction of the Jebel Aulia Dam by the Egyptian Government. The largest scheme is at Abd el Māgid, which is in effect a special extension of the Gezira gravity irrigation scheme. Smaller schemes situated at Fatīsa, Hashāba, and Umm Gerr are irrigated by pump from the White Nile.

The profit-sharing arrangement applied in the Gezira has been applied to these schemes except that the Government have fulfilled a dual role by eliminating the third partner.

Season 1938/9 was the first one to produce cotton, and the results to the Government since 1939 have been as follows:

Year	£E.	Year	£E.
1939	12,038	1941	34,230
1940	26,195	1942	155,492

(iii) *Kassala Cotton Scheme*

When cotton was first cultivated by irrigation in the delta of the river Gash the Government took as rent and taxes one-fifth of the value of the cotton grown. The scheme was later managed by the Kassala Cotton Company. The concession agreement provided for a division of the gross proceeds of the cotton crop on a partnership basis, viz. 50 per cent. to the tenants and the remaining 50 per cent. to the Government and the company. In 1928 the Government relieved the company of its concession and a special board, known as the Gash Board, was constituted and assumed the responsibilities of the company. The Board was financed by the Government, but its accounts are kept on commercial lines and quite distinct from those of the Government, which contain only the share in the proceeds of the cotton crop which would have accrued to them under their concession agreement with the Company.

The Government's share from Gash cotton, exclusive of the Gash Board's share or any portion of it, during the 7 years 1936–42 was:

Year	£E.
1936	56,000
1937	16,229
1938	25,000
1939	23,000
1940	68,184
1941	46,782
1942	50,793
Average	40,855

During those years the Gash Board declared no dividends (i.e. no part of its profits was passed on to the Central Government), the whole of its share being utilized to build up a strong reserve position against bad years, to provide working capital and development expenditure, and to repay the amount due to the Kassala Cotton Company on the termination of its concession.

(iv) *Tokar*

Cotton is grown in the delta of the river Baraka under conditions similar to those in the Gash Delta. But here the Government deal directly with the cultivators. Up to 1937 the Government took 25 per cent. of the value of the cotton (which is sold by auction in Tokar itself) in return for the tenancy, the seed, supervision, and taxes, and the tenant took the remaining 75 per cent. From that date the Government in order to help the tenants with their cultivation expenses allotted one-fifth of their share, i.e. 5 per cent. of the gross proceeds of the crop, to a special financing account. The reserve thus provided, however, proved inadequate, and in 1942 a levy was imposed upon the tenants to bring the total payment to the tenants' financing account up to 10 per cent. of the gross proceeds; the Government and the tenants thus contributing towards future seasons' expenses on a fifty-fifty basis. The value of the cotton crop is therefore now divided up as follows: to the Government 20 per cent., to the tenant 70 per cent., and to the tenants' financing account 10 per cent.

The Government's share from Tokar cotton during the 7 years 1936–42 was:

Year	*£E.*
1936	30,894
1937	86,591
1938	10,423
1939	37,373
1940	42,312
1941	49,524
1942	21,224
Average	39,763

(v) *Government Pumping Schemes*

There are several pumping schemes in Northern and Blue Nile provinces on which natives cultivate under the supervision of Government agricultural inspectors. In normal times American cotton was the most important crop, but wheat, maize, &c., were also grown and certain schemes were wholly confined to food crops, there being no intention of growing cotton on them.

In the Northern Province there were two groups, the Berber group and the Dongola group. In the Berber group the proceeds of both cotton and grain were divided on a fifty-fifty basis between the Government and the tenant; in the Dongola group the tenant received the whole of his grain crop but was paid only 1 millieme a rotl of seed cotton produced. All Northern schemes are now confined to the growing of food crops, the tenants paying fixed water rates.

In the Blue Nile two schemes produce Sakel type cotton and the terms of cultivation are on similar lines to those in force in the Gezira Scheme.

There are also seed-supply farms at various stations.

The Government's gross revenue from these schemes over the 7 years 1936–42 was:

Year	*£E.*
1936	31,858
1937	35,278
1938	22,310
1939	23,713
1940	15,563
1941	47,717
1942	51,555
Average	32,570

(vi) *Rain-grown Cotton*

No direct revenue accrues to the Government from the development of this industry.

In normal times considerable quantities of rain-grown cotton are produced in Kordofan and to a lesser extent in Upper Nile and Equatoria. In its early days the industry had to be subsidized by the Government. Surplus profits which have accrued since the industry became established are held in trust by the Government as an equalization fund for the benefit of the cultivators.

Cultivation is under Government supervision, and a sum of £E.10,000 per annum is recovered from the proceeds of the cotton towards the cost of providing the services rendered.

Other Government Commercial Undertakings

(i) *Ginning Factories*

Outside the Gezira, the Government own all the country's cotton ginning factories with the exception of privately owned units at Suakin and Zeidab. The largest factory is at Port Sudan, which normally gins, with the help of Suakin, the sakel output from the Gash and Tokar cotton areas. Sakel cotton from privately owned pumping schemes on the White Nile and from the two Government pumping schemes in the Blue Nile together with American rain-grown cotton from the Upper Nile are dealt with at Sennar. Atbara has until recently ginned the cotton produced in the Northern Province and private estates in Khartoum. Four small conveniently placed units gin the rain-grown output of the Equatoria Province and six similarly placed units deal with the Kordofan American rain-grown crop.

Gross revenue from these factories over the 7 years 1936–42 was:

Year	*£E.*
1936	87,203
1937	105,957
1938	93,878
1939	76,321
1940	78,558
1941	80,714
1942	80,986
Average	86,231

(ii) *Timber and Firewood*

In order to reduce inroads on desert scrub and to prevent the indiscriminate cutting of forest areas the Government adopted a policy of concentrating, so far as possible, all wood-fuel requirements in forest reserves, and thus became the country's main supplier of that commodity. Saw-mills originally set up to provide sleepers for the Sudan railways have gradually extended their activities to the production of building and other commercial timber. Revenue from these two sources is considerable, as will be seen from the following statement of receipts over the 7 years 1936–42:

Year	*£E.*
1936	28,588
1937	58,356
1938	35,926
1939	36,872
1940	58,617
1941	139,706
1942	172,350
Average	75,774

VI. Summary

The total budgetary revenue of the Sudan Government (inclusive of that collected by local administrations) in 1942 was £E.5,894,591. Of this £E.2,236,756 was derived from land and crops made up as follows:

	£E.	*£E.*
Direct taxes		
Land tax	24,244	
Date tax	22,317	
'Ushūr'	51,720	
		98,281
Royalties		
Gum	129,170	
Other	43,891	
		173,061
Customs		
Export duty on Sudan produce		53,275
Cotton		
Gezira Scheme	1,369,829	
White Nile Alternative Livelihood Schemes	155,492	
Kassala Scheme	50,793	
Tokar	21,224	
Pumping-schemes	51,555	
Rain-grown Schemes	10,000	
		1,658,893
Ginning factories		80,896
Timber and wood fuel		172,350
Total		£E.2,236,756

or nearly two-fifths of the Government's total budgetary revenue.

In addition to this large direct contribution to the general revenues of the country it must be borne in mind that land and crops must necessarily affect other receipts to the Central Government. Freight on cotton and

other crops swell the gross revenues of the Sudan Railways. Good crop years are reflected in the profits from the Government monopoly of the import and sale of sugar and in the receipts of the Customs Department from import, &c., duties, and although small agricultural schemes are exempted from business profits tax, a large proportion of this tax is directly due to crop production. In short, revenue from land and crops is by far the greatest influence upon the financial well-being of the Sudan.

Chapter XII

THE PROBLEM OF LAND FRACTIONATION

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Introduction

IN Muslim parts of the Sudan agricultural lands and even ownership of individual date-palms have become subdivided in accordance with normal laws of inheritance, operating through sharia law, until in places the stage has been reached in which the owners are possessed of so small a feddanage of land that they cannot support a family upon it. This process is here called land fractionation but might equally well be called hereditary subdivision of agricultural land. It results in the Sudan in the poverty and undernourishment of rural populations that only a few generations ago must have been prosperous and well fed. It is not that the land goes out of cultivation, though this is frequently a result, but that it becomes unable to support an increased population.

The problem is potentially a serious one because it is liable to develop in the case of most of the valuable riverain lands between Khartoum and Wadi Halfa. The process is insidious because slow. There is a very real danger that the happy prosperous community of excellent people based on the freehold 'sāqiya' lands north of Khartoum may through the operation of this process and through no fault of their own become poverty stricken and discontented.

An Example of Poverty due to Land Fractionation

It is difficult in general terms to describe the stage of civilization reached by a community, but village surveys bring out the main points clearly as they enable us to focus attention upon the way in which a few real people live and give a close-up view that seems to have vitality and meaning.

On some freehold land watered by the Nuri Pump Scheme the stage of poverty and undernourishment has been reached and the results of a little survey conducted by T. D. Bevan and the writer in 1940 may help to illustrate the matter. Thirteen households were examined, these having been selected as fair average samples for the area. A summary of the information collected follows in more or less tabular form (for A, *The Household*, see opposite):[1]

(B) *Situation of Houses*

House 1. Was a 'matara'[2] freehold homestead prior to pump scheme, situated outside the date belt of the river bank.

House 2. Part of a group of houses representing a 'matara' freehold homestead prior to pump scheme.

House 3. Was on the river bank in the date belt, but house was washed

[1] These tables of dry facts are given for record and for the use of students. The ordinary reader should proceed to p. 220.

[2] A 'matara' is a 'sāqiya' or Persian wheel operating at a well.

away by the erosion of the river bank 3 years ago; the owner then built a temporary leaf house and lost all his effects in a fire. Now lives with nephew pending construction of new house.

House 4. Among the dates about ½ km. from the river bank.

House 5. In the date belt near the river.

House 6. In the date belt near the river near the mouth of canal No. 8.

House 7. In the date belt. It is one of 4 houses occupying about 1 feddan within a retaining wall that probably represents the houses of a 'sāqiya' owner prior to pump scheme.

House 8. Near river bank in date belt near mouth of canal No. 8. One of 6 houses within one retaining wall.

House 9. Outside the date belt and one of a group of 4 houses on a site close to Citrus Experiment Farm representing remains of a 'matara' freehold.

House 10. Situated in down-river end of date belt.

House 11. In date belt near Saggai. His deceased brother's house in same compound.

House 12. In the village of Saggai. No compound.

House 13. Under palms in Gereit village near Saggai with a walled compound.

(A) *The Household*

House	*Husband*	*Wives*	*Boys*	*Girls*	*Mother*	*Sisters*
1	1	0	..	..	1	2
2	1	1	1 baby	1 (5 yrs.)	..	..
3	1	1	1	..	..	..
4	1 (v. old)	1	1 (14 yrs. works out); 1 baby.	1 (14 yrs.)	..	..
5	1	1	1 (3 yrs.)	..	1	..
6	1	1	1 (10 yrs.)	1 (14 yrs.)	1	1
7	1	1	1 (10 yrs.); 1 (6 yrs.); 1 (3 yrs.)	..	..	..
8	1 (old)	1	1 (25 yrs.)	2	..	..
9	1 (age 55)	2	1	1 (15 yrs.)	..	..
10	1 (age 50)	1	1 (15 yrs.); 1 (11 yrs.)	3	..	..
11	1 (age 50)	1	1 (9 yrs.); 1 (7 yrs.)	4 (all under 7).	..	..
12	1 (age 35)	1	1	1 (7 yrs.); 1 baby.	..	..
13	1 (age 65)	1 living	..	1 (married); 1 (age 7); 1 (age 4)	..	..

(C) *Daily Habits in regard to Food*

House 1. 6.30 a.m. Tea with milk and sugar. 11 a.m. 'Kisra'[1] with side dish or flavouring of onions, 'lubia hilu',[2] 'bamia',[3] tomatoes in season,

[1] 'Kisra' consists of flat cakes of unleavened bread usually made of dura flour.
[2] 'Lubia hilu' or sweet lubia is a local name for *Vigna unguiculata* (L.) Walp.
[3] 'Bamia' is *Hibiscus esculentus* Linn.

and salt. After lunch, a cup of tea. 6 p.m. Another 'kisra' meal much like the 11 a.m. one. Meat about twice a week, the price being ¼ oke or a handful for 1 P.T.

House 2. 6.30 a.m. Tea with milk or sugar. 11 a.m. 'Kisra' with flavourings such as salt, 'lubia', onions, tomatoes, an occasional melon, and dates in season. In the evening another 'kisra' meal. Meat about twice a fortnight.

House 3. 6.30 a.m. Tea with milk and sugar. 12 noon. 'Kisra' with salt and in season 'bamia', 'bamia' leaves, 'lubia 'afin' seeds,[1] onions, dates, 'batikh',[2] 'shammam',[3] and marrow. Meat once a week.

House 4. 6.30 a.m. Occasionally tea with milk and sugar. 12 noon. 'Kisra' with in season 'bamia' and 'bamia' leaves ('sabarok') and dates. 7 p.m. Ditto. Seldom has meat. Occasionally uses wheat in 'kisra'. Buys half a piastre's worth of vegetables a week from the suk.

House 5. 6.30 a.m. Tea with milk and sugar. 8.30 a.m. 'Kisra' with 'bamia' and dried meat ('sharmūt'), with fresh meat every 4 days or so. 2 p.m. 'Kisra' and 'bamia' leaves and in season 'melokhia', 'lubia' seeds, and onions. 3 p.m. Tea and sugar, no milk. 8 p.m. Remainder of 'kisra'.

House 6. 6.30 a.m. Tea with milk and sugar. 11 to 12 noon. 'Kisra' with 'bamia' or 'lubia' leaves. 8 p.m. Ditto. Meat seldom.

House 7. 6.30 a.m. Tea with milk and sugar. Midday, 'kisra' with 'bamia' leaves and flavourings such as onions, 'lubia hilu', and tomatoes. Evening, 7 p.m. Tea and 'kisra' meal. Meat about once a month. Uses a little wheat in season mixed with dura. Uses about 50 lb. of dates a year.

House 8. 6.30 a.m. Tea with sugar and milk. 11 a.m. 'Kisra' and 'bamia' leaves and salt. Onions, dates, radishes occasionally in season.

House 9. 6.30 a.m. Generally has tea with milk and sugar. Principal meal 3 p.m. 'Kisra' with 'lubia' and 'bamia' leaves and salt. Once a week onions. 7 p.m. Uses 'lubia 'afin' seeds boiled green ('balilla'). Meat twice a week.

House 10. 6.30 a.m. Twice a week has tea with milk and sugar. 11 to 12 noon. 'Kisra' with 'bamia' leaves or 'lubia hilu' or onions. Sometimes has 'lubia 'afin' seeds parched. Sometimes has an evening meal based on 'kisra'.

House 11. 6.30 a.m. Four days a week tea. Noon, 'kisra'. 7 p.m. 'Kisra' or 'dukhn'[4] bread if no dura in house. Meat once in 15 days.

House 12. Early morning tea. About noon, 'kisra' or 'balilla'. Takes dates in pocket for eating in field. 'Kisra' in evening when he has grain. Meat only on high days and holidays.

House 13. Early morning tea. About noon, 'kisra' with vegetables bought in the market. 'Kisra' grain in evening. Meat very seldom on holidays and feast days.

[1] 'Lubia 'afin' or stinking 'lubia' is the local name for *Dolichos lablab* Linn. When prepared for food it is fermented and at this stage is "afin'.

[2] 'Batikh' is water-melon, *Citrullus vulgāris* Schrad.

[3] 'Shammam' is melon, *Cucumis melo* Linn.

[4] 'Dukhn' is Arabic for *Pennisetum typhoideum* Rich.

(D) *Domestic Water-supply*

People often use water from inside the 'zīr'.[1] Such water is cool but not filtered.

House 1. Water from canal. 'Zīr' on stand in use.
House 2. Water from canal. 'Zīr' on stand in use.
House 3. Water from river. 'Zīr' on stand in use.
House 4. Water from river or canal. 'Zīr' in use.
House 5. Water normally from canal. 'Zīr' on stand in use.
House 6. Water from canal or river. 'Zīr' on stand in use.
House 7. Water from 'gadwal'.[2] 'Zīr' on stand in use.
House 8. Water from 'gadwal'. 'Zīr' on stand in use.
House 9. Water from 'gadwal'. 'Zīr' on stand in use.
House 10. Water from 'gadwal'. 'Zīr' on stand in use.
House 11. Water from canal. 'Zīr' on stand in use.
House 12. Water from well. Uses 'zīr'.
House 13. Water from canal. No 'zīr' but earth pots for carrying.

(E) *Type of House*[3]

House 1. In a group of houses representing the subdivision of a 'matara' holding prior to pump scheme. Good condition. 4 large rooms. Mud walls. 'Dōm'[4] rafters.

House 2. In a group of houses representing the subdivision of a 'matara' holding prior to pump scheme. 2 rooms and a kitchen. Clean. Mud walls. 'Dōm' rafters.

House 3. As No. 2.

House 4. In the huddled collection of houses or straggling village in date belt representing the 'sāqiya' homesteads. 2 rooms and a kitchen. Fair condition. Mud walls. 'Dōm' rafters.

House 5. Situation as No. 4. 3 rooms and a kitchen. Mud walls. 1 room with date log roof, remainder 'dōm'.

House 6. Situation as No. 4. A guest house of 2 rooms and a women's quarter of 2 rooms and kitchen. Mud with date and 'dōm' rafters.

House 7. Situation as No. 4. 4 houses in group. 2 rooms large and in good condition. Roof of split date and 'dōm' rafters or beams. Walls old. Roof new. Height 11 ft.

House 8. Near river bank. 5 or 6 houses in the group. 3 rooms and kitchen. Mud walls. 1 'dōm' beam and remainder date splits ('nahla'). Condition good.

House 9. A 'matara' site. 4 rooms and a kitchen. Built by father. In reasonable condition. Roof beams of 'dōm', dates, and 'harāz'.[5]

House 10. In northern end of date belt. 5 rooms with 3 brothers living

[1] A 'zīr' is a large porous earthenware pot mounted on a stand for cooling and filtering water.
[2] 'Gadwal' is a small canal.
[3] All are rectangular and have a flat roof covered with earth. Cool and suitable for the desert climate that prevails.
[4] 'Dōm' is the palm *Hyphaene thebaica* Mart.
[5] 'Harāz' is Arabic for *Acacia albida* Del.

together. Only 2 rooms are roofed, others have fallen in. Mud construction. Rafters 'dōm' and 'harāz'.

House 11. In northern end of date belt. Unoccupied dead brother's house in compound. House built by father. 1 room and kitchen. 'Dōm' and date rafters. Walls in good condition. Roof only fair.

House 12. Situated in Saggai. No compound. 2 rooms. Date beams. Built by owner 14 years ago and condition good.

House 13. Situated in Gereit village. Walled compounds. 1 room and small kitchen. Roof of split date trunks. Built many years ago by owner and condition now poor.

(F) *Household Effects*

House 1. 3 'angarīb',[1] 1 chest, 1 'zīr', 1 prayer mat, 1 wash-basin, 2 tea-pots, 3 cups, 1 saddle.

House 2. 4 'angarīb', 2 boxes, 1 'zīr', 1 prayer mat, 1 wash-basin, 1 coffee-pot, 1 tea-pot, 4 cups (glass), 1 spoon. Several cooking-pots, 1 saddle. An imposing array of 15 Kordofan wooden bowls ('gadah') slung from roof in plaited rope cradles; these brought into house by wife and are objects of considerable beauty.

House 3. 5 'angarīb', 1 trunk, 1 'zīr', 1 prayer mat, 2 small tables, some wooden dishes, 1 tea-pot and 4 glass cups, 2 metal cooking-pots. Most of these destroyed in fire.

House 4. 3 'angarīb', 1 'zīr', 1 stool, 1 little table, 1 tray and tea things, 2 glass cups, no coffee things, 1 earthenware cooking-pot, 1 enamel dish, 1 spoon, 1 trunk.

House 5. 5 'angarīb', 1 'zīr', 1 trunk for sugar, 1 large and 1 small table, 2 tea-pots, 1 kettle, 5 glass cups, 4 enamel food bowls, 1 spoon, 1 donkey saddle for carrying manure.

House 6. 5 'angarīb', 1 'zīr', 1 lock-up box for tea, sugar, &c., 3 small tables, 2 enamel food bowls, 1 spoon, 1 kettle, 1 tea-pot, 1 saddle for donkey.

House 7. 4 'angarīb', 2 mattresses, 2 pillows, 1 beautiful embroidered sheet, a present from a brother in Gash. 3 'angarīb' mats, 2 metal trunks, 1 small table, 1 primus stove, 1 chair, 1 washing-basin, 1 lantern with glass, 1 old saddle, 1½ sacks of dura.

House 8. 6 'angarīb', 1 'zīr', 1 wash-dish, tea things, 1 small table, 5 mattresses, 1 small box, 2 cooking-pots, 1 saddle, 1 glassless lamp.[2]

House 9. 4 'angarīb', 1 small table, 1 aluminium cooking-pot, 1 box, 1 saddle, and 1 lamp without glass.

House 10. 3 'angarīb', 1 mat, 1 set of tea things, 1 coffee set, 1 wood and 1 metal trunk, 2 wooden dishes, 1 cooking-pot, 1 small table, 1 saddle, a glassless lamp.

House 11. 5 'angarīb', 1 small table, 2 aluminium pots, no large basin, 1 tea-pot and 2 glass cups, 2 wooden basins, 1 gourd, 1 china and 3 metal basins, 2 wooden boxes, 1 donkey saddle, 1 glassless lamp.

[1] An 'angarīb' is a bed with four stout, often nicely worked, wooden legs with a mattress made of woven rope locally spun from the leaves of the 'dōm' palm.

[2] The glassless lamp referred to is made by the local tinsmith, burns kerosene oil, and produces more smoke than light; it has no chimney.

House 12. 3 'angarīb', 1 small table, 1 aluminium cooking-pot, tea-cups, 1 washing-pan, 3 metal basins, 3 wooden bowls, 2 wooden boxes and 1 metal trunk, 1 saddle, 1 rug, 1 leather skin for storing grain, 1 glass-less lamp.

House 13. 2 'angarīb', 1 small table, 1 aluminium cooking-pot, tea-pot and glass cups, 1 wooden and 2 enamel bowls, 1 broken hurricane lamp and 1 local glassless lamp.

(G) *Livestock*

House	*Camels*	*Bull*	*Cow*	*Calves*	*Heifers*	*Donkey*	*Sheep*	*Goats*
1	..	..	..	..	..	2	3	1
2	..	..	..	..	..	1	3	..
3	..	..	..	..	..	1	..	3
4	'My God no much too poor.'*					..	..	1
5	..	2 (½ share)		..	..	1	3	1
6	..	..	..	..	..	1	3	..
7	..	..	..	..	..	(1 large) (2 small)	..	2
8	..	..	..	..	..	1	..	2
9	..	..	..	..	..	1	..	2
10	..	..	..	..	..	1	..	1
11	..	..	..	..	..	(1 mort-gaged)	1	3 (½ share)
12	..	..	1	..	..	1	5 (3 lambs)	..
13	..	..	..	..	..	..	3† (2 lambs)	1 kid

* The idea of being wealthy enough to own any animal other than one goat was regarded as a great joke.

† Owned by the merchant.

(H) *Milk Supply*

House 1. ½ rotl[1] of sheep and goat milk per day.
House 2. ½ rotl of sheep milk per day.
House 3. 1 rotl of goat milk per day.
House 4. 1 cup of goat milk per day.
House 5. 1 to 1·5 rotls of sheep and goat milk per day.
House 6. 1·5 to 2 rotls of sheep milk per day.
House 7. No milk but shares with a relative.
House 8. ½ rotl of goat milk per day.
House 9. ½ rotl of goat milk per day.
House 10. ½ rotl of goat milk per day.
House 11. 2½ to 3 rotls of goat and sheep milk per day.
House 12. 3 to 4 rotls of cow's milk per day.
House 13. ½ rotl of goat milk per day.

(I) *Forage for Animals*

House 1. 'Lubia' will last to early March, then grass and weed pickings from canal banks, then wheat straw.

[1] A 'rotl' is almost exactly a pound.

House 2. 'Lubia' will last to March, then weeds and grass from canal banks, then wheat straw, then 'seifi'[1] dura.

House 3. 'Lubia' to March. Then 'qassab'[2] now in store. Canal picking. Wheat straw.

House 4. No 'lubia'. A little 'qassab'. Pickings.

House 5. 'Lubia' to March, then canal pickings, 'qassab' (in store), and wheat straw.

House 6. 'Lubia', then grass and weed pickings, then dura leaves.

House 7. 'Lubia' to end of February. Then a little grass, date windfalls, and wheat straw.

House 8. 'Lubia' to 15 March, then a little 'qassab', wheat straw, and 'seifi' dura.

House 9. 'Lubia'.

House 10. 'Lubia' and 'qassab'.

House 11. From cultivations. (This probably means like House No. 3. —J. D. T.)

House 12. Buys a little 'dukhn' for the animals. 'Lubia', wheat straw, and 'qassab'.

House 13. Cuts grass and 'lubia', some 'qassab' in store.

(J) *The Land and Crops*

House 1. Freehold land. Including dates, bare ground, house area, and crops the total area is less than 3 feddans, and it is in little bits representing interests in subdivided 'sāqiya' holdings now included in the pump scheme. Has 55 date-trees and pays about £E.2.00 date tax of 1·5+2 P.T. per tree; trees planted by his father, now old, and crop has declined rapidly and recently and is now down to 2 ardebs. 'Seifi' dura $\frac{1}{6}$ feddan, 'dameira'[3] dura $\frac{1}{6}$+'lubia' $\frac{1}{10}$; 'shitwi'[4] wheat $\frac{1}{6}$ feddan. 2 'hōd'[5] of onions, no 'bersīm'. Also has a third of a feddan interest in another 'sāqiya.'

House 2. Freehold. Has shares in 4 'sāqiya'. 4 date-trees, produce of which he eats. 'Seifi' dura $\frac{1}{6}+\frac{1}{6}+\frac{1}{8}+\frac{1}{8}$ feddan. 'Dameira' dura $\frac{1}{6}+\frac{1}{6}+\frac{1}{8}+0$ feddan. 'Lubia' follows 'seifi' dura. 'Shitwi' wheat $\frac{1}{6}+\frac{1}{6}+\frac{1}{8}+\frac{1}{8}$ feddan. 'Fasulia'[6] $\frac{1}{10}$ feddan. Onions 3 'hōd', 'bamia' 2 hods. Yield of seifi' dura 168 lb., of 'dameira' dura 14 lb., and he consumes 70 lb. a month. Yield of wheat 500 lb., price £E.1.44 per ardeb of 334 lb. He sells an occasional sheep.

House 3. Freehold. Shares in 3 'sāqiya'; total land 1·5+1·5+0·66 feddans. Pays date tax of £E.1 for 30 trees that yield 30 keilas of 28 rotls that he sells for 3 P.T. the keila. Some of the trees old and all are wrong kind, being 'gow' or seedlings. 'Seifi' dura 392 lb., no 'dameira' dura. Wheat $\frac{1}{3}+\frac{1}{3}+\frac{1}{6}$ feddan, yield 885 lb., value £E.3.80. No 'fasulia', 'ful masri',[7] or onions.

[1] 'Seifi' = summer.
[2] 'Qassab' is the local Arabic name for dura straw.
[3] 'Dameira' = autumn.
[4] 'Shitwi' = winter.
[5] 'Hōd' = a small plot.
[6] 'Fasulia' is the local Arabic for haricot beans.
[7] 'Ful masri' is the local Arabic for horse beans.

House 4. Freehold. Has a fractional interest only in 1 'sāqiya' and excluding house his land is 0·5 feddan. Has 20 date-trees, mostly young, and has sold 30 keila (840 lb.) for 60 P.T. and has consumed 6 keila. Wheat 0, 'lubia' 0. 'Seifi' dura 0·5 feddan; yield 840 lb.

House 5. Freehold. Has a fractional interest in 4 'sāqiya' and his land adds up to 2 feddans. Dates: pays tax of £E.1.40; trees yield 80 keila and sold for 4·5 P.T. the keila = £E.3.60. 'Seifi' dura 0·5 feddan produced 21 keilas or 588 lb. Winter wheat 1 feddan, some on hired land, produced 60 keila which he sold for 12 P.T. or £E.7.20. 'Lubia' 0·25 feddan, sold 8 keila of seed for 32 P.T.

House 6. Freehold. 40 date-trees, mostly old, of poor 'gow' type and badly watered. Only 25 yielding, produced 40 keila and sold crop for £E.1.80. 'Seifi' dura 0·2 feddan and produced 7·25 keila or 202 lb. Wheat $\frac{1}{4}$ feddan attacked by rust and no crop. 'Lubia 'afin' $\frac{1}{5}$ feddan and produced 'balilla' for humans and fodder for animals. Sells a few 'lubia' leaves at Kareima.

House 7. Freehold. Has an interest in 4 'sāqiya'. Pays £E.2.40 date tax and has approximately 75 trees. Yield 90 keila sells at 4 P.T. or £E.3.60, Barakawi mostly. 'Seifi' dura yield 6 keila and 'dameira' dura 3 keila. Wheat $\frac{1}{10}+\frac{1}{6}+\frac{1}{9}+\frac{1}{6}$ feddan or 0·53 feddan produced 15 keila worth 8 to 10 P.T. the keila. 'Lubia 'afin' $\frac{1}{6}+\frac{1}{10}+0+0$.

House 8. Freehold. An interest in 1 'sāqiya' only and cultivable land including dates $\frac{1}{2}+0{\cdot}14$; dates all 'gow' except 1 Barakawi. Yield about 14 keila; may consume 5 keila, price 1·5 to 2 P.T. the keila; total revenue for dates say 20 P.T. 'Seifi' dura $\frac{1}{6}$ feddan produced 6 keila; 'dameira' dura 4 keila. Wheat $\frac{1}{6}$ feddan produced 9 keila, of which he sold 3·5 keila for 42 P.T. 'Lubia' $\frac{1}{6}$ feddan.

House 9. Freehold. Has an interest in each of 3 'sāqiya'. Including house he has 4 feddans, 40 date-trees—crop last year sold for £E.5.00. 'Seifi' dura $\frac{1}{2}$ feddan produced 16 keilas, 14 of which sold to meet water rate. 'Dameira' dura 6 keilas from $\frac{1}{2}$ feddan. Wheat $\frac{1}{6}+\frac{1}{6}+\frac{1}{6}$ feddan, yield 12 keila that he sold for £E1.32. 'Lubia' $\frac{1}{3}$ feddan.

House 10. Freehold. Has an interest in 5 'sāqiya'. Total land $0{\cdot}11+0{\cdot}15+0{\cdot}09+0{\cdot}12$ feddan or just under 0·5 feddan. 5 date-trees consumes most of the crop but sells 3 to 4 keila at 2.5 P.T. Winter wheat on $\frac{1}{2}$ feddan and expects 672 lb. of wheat if lucky. All land then to 'seifi' dura and expects 37 keila worth £E.2.59 less water rate of 60 P.T. or £E.1.99 net. 'Lubia' $\frac{1}{3}$ feddan.

House 11. Freehold. Interest in 2 'sāqiya' $\frac{1}{4}+\frac{1}{2}$ feddan. Wheat crop 7·5 keila, 5 sold at 11 P.T. for 55 P.T., balance consumed. Dura 'seifi' produced 560 lb., of which he sold 140 for £E.1.96. 'Dameira' dura 2 keila consumed. 'Lubia' $\frac{1}{4}$ feddan, some sold at Kareima; 33 date-trees, 20 'gow' and 13 Barakawi, 15 to 20 keila respectively, for £E.1.12. Father planted 15 'gow' and 5 Barakawi and present owner 10 'gow' and 30 Barakawi.

House 12. Freehold. Has an interest in 1 'sāqiya' of 1·25 feddans. Works on another 'sāqiya' for half the crop on 0·5 feddan of wheat. 12 date-trees, some not yielding, 2 are Barakawi and 10 'gow'; his father planted most of them; he has planted 5; yield 6 keila, sold enough to pay water and date tax and consumes remainder. Wheat 9 keila, 252 lb., from 0·25 feddan,

sold some and has eaten some; 'seifi' dura 252 lb. from 0·25 feddan, all consumed; 'dameira' dura 15 'hōd', 56 lb.; 'lubia' sown with 'dameira' 15 'hōd' for animals.

House 13. Freehold. Owns 0·5 feddan of 1 'sāqiya'. Has 20 date-trees, all 'gow', planted them himself. Sells most of crop for date and water tax. Wheat 12 'hōd' yield 56 lb.; borrowed seed from merchant and returned equal quantity, consumes remainder. 9 plots 'seifi' dura yield 56 lb., followed by 5 of 'fasulia' and 4 of 'lubia'.

(K) *Gardens—Fruit and Vegetables*

House 1. No garden.

House 2. Onions 3 plots, 'bamia' 2 plots. No fruit.

House 3. No garden.

House 4. No garden. Buys 0·5 P.T. worth of vegetables per week from suk.

House 5. 1 lime-tree and sows each year 'bamia', 'molukhía', 'shabbat', 'lubia', 'tlab', and 'shata' in season.

House 6. No garden.

House 7. No garden. Spends 2 P.T. per week for vegetables from suk.

House 8. 2 'hōd' each of 'bamia' and 'fasulia' and $\frac{1}{10}$ feddan on 'gerf' or river bank.

House 9. 4 'hōd' of onions. No 'bamia' or 'molukhia' at this season.

House 10. 1 'hōd' of 'bamia' and 1 of onions. Borrows and shares vegetables with friends.

House 11. No garden, but has 2 'hōd' of 'bamia'.

House 12. No garden, but 2 'hōd' of 'bamia' in 'seifi' area.

House 13. 4 'hōd' alongside house. 2 lime-trees. 4 pepper bushes, 3 sunt trees.

(L) *Financial Relations with Sūk*

House 1. No dura left and household consumes 28 lb. in 25 days. Now buys for 8 P.T. cash or 9 P.T. credit from any one of 4 merchants. Debt at suk normally runs up to £E.3 at its peak.

House 2. Commenced buying dura at sūk in November. Uses 70 lb. per month. Price 7 to 8 P.T. from one merchant. Debt normally rises to £E.4 at peak.

House 3. Commenced buying dura on 1 January. Uses 28 lb. a week. Price 8 P.T. from any merchant. Debt normally rises to £E.3, which he pays with wheat, dura, and dates.

House 4. Gets credit from several merchants. Price of dura 7·6 P.T. (cash). Now owes £E1.5 and expects this to rise to £E.4. Pays debt with dates and dura only.

House 5. Seasonal indebtedness for sugar and clothes rose last year to £E.8. Dates paid off £E.4, and wheat £E.2; balance still unpaid. He still lives off his own dura and has 112 lb. left.

House 6. Is drawing tea, sugar, and dura (8 P.T.) on credit from merchant. Dura finished 20 days ago. Debt so far 90 P.T.

House 7. Bought 2 bags of dura 20 days ago at 35 P.T. the sack of 7

keilas plus 5 P.T. porterage = 5.36 P.T. the keila of 28 lb. Debt to merchants now £E.2; normally rises to £E.4. Pays off debt mostly with dates, partly with wheat, and any small balance with dura.

House 8. Deals with various merchants. Debt normally rises to £E.3. Repays with dates, wheat, and dura and sells some 'qassab', but wheat the main item.

House 9. Debt now £E.8, this being customary peak. Repays mostly with dates, partly with wheat.

House 10. Has no credit account with one merchant only. Total indebtedness now only 7 P.T.

House 11. Commencing to buy dura now (February). Debt rises to £E.5 or £E.6. Repays with dates and wheat.

House 12. Deals with one merchant. Commenced to purchase dura in February. Debt rises to £E.2 or £E.3. Repays with wheat.

House 13. Now owes 60 P.T. and this will increase to about £E.2 before wheat harvest. Buys about 42 lb. of dura per week for 2–3 months. Receives some income from stringing 'angarīb'. The rope 6 m/m. per hank and 1 P.T. for stringing.

(M) *Comparative Position Ten Years Ago*

House 1. Not as well off as 10 years ago; date crop has fallen from good yield to almost nothing and other crops not as good as formerly.

House 2. Is certain that he was better off 10 years ago and remembers a time when cotton fetched £E.3 the kantar.

House 3. Says he is very poor and was equally poor 10 years ago.

House 4. Says he was better off 10 years ago. He then ate more meat and drank beer. Date crop used to be better and he remembers cotton fetching £E.10 the kantar. People then could pay their way. Says he is very poor. The boy in mill earning £E.2.40 per annum is now propping up the financial structure of this household, entirely poor but most cheerful.

House 5. Is better off than 10 years ago, but can give no reasons except that he thinks his cultivations are better.

House 6. Thinks he is a little better off than 10 years ago. Has small plot on island opposite where he grows less than a bag of dukhn.

House 7. 10 years ago date-trees were younger and yielded better. Mostly planted by grandfather. Apart from age he thinks the yield from trees in their prime is less now than it was 10 years ago.

House 8. Says he is very poor. Was better off 10 years ago when the dura crop was much better. Also he was younger then and used to go out to work at Wad Medani, Barakat, and Omdurman.

House 9. Says he was better off 10 years ago as date and cotton prices were much higher. His dates planted by his father now yield better than formerly.

House 10. Worked for 6 years at Port Sudan. Now lives at home permanently. Says he was better off 10 years ago as cotton prices were good and paid all his taxes.

House 11. Is worse off than 10 years ago and has a large family to support. Has no regrets, as he says they will eventually support him.

House 12. Man of limited intelligence. Says he is well off.

House 13. Says he was better off 10 years ago. Is very old and has a young family to support.

General Comments on the Survey

In general the householders and their families were a rather poor lot of people physically, appeared to be undernourished, and were obviously very poor. Their dwellings were spacious and generally in good order and clearly a relic of better times prior to the minute subdivision of the land. The daily habits in regard to food show that tea, coffee, sugar, and milk were used very sparingly, that the meat intake was entirely inadequate, and that there was a marked shortage of vegetables and fruit. In the matter of household effects one was saddened to go into a house where one was treated with the greatest courtesy, and made to drink probably the whole week's supply of tea or coffee or both in one magnificent half-hour, to have solemnly to write down the entire contents of the house as, for instance (house No. 11), 5 beds, 1 occasional table, 2 aluminium pots, 1 teapot, 2 glass cups, 2 wooden basins, 1 gourd, 1 china and 3 metal basins, 2 wooden boxes, 1 donkey saddle, and 1 smoky little lamp without a chimney as the entire list of household property of an elderly man, a wife, and six children all under 9. Poverty was also indicated by the almost entire absence of camels, bulls, cows, calves, and heifers. The milk supply from goats and sheep was much too small for a healthy community and could not be greater because land could not be spared for the growing of additional forage. The impossibility of providing for the emergence of a happy, prosperous, healthy rural community taking a full part in the benefits of civilization was shown very clearly in the tabulation of land and crops, and the big fact that emerges is that notwithstanding the date palms that slightly ease the economics of the community the 3 feddans or less of land available for each household is not nearly sufficient to enable any sort of emergence to take place. Poverty is again reflected in the financial relations with the sūk, particularly in the perennial indebtedness.

The Remedy

The slow process of impoverishment illustrated by the above survey can be seen in all sorts of stages in the river lands north of Khartoum.

The ideal remedy would be for Government to buy up or lease all the riverain land, to redistribute on a household basis in holdings large enough to provide for the emergence of a prosperous, healthy community; and to provide alternative livelihood for displaced population.

Alternative livelihood could be provided along the river up to the somewhat narrow limit of the suitable land available by the installation of pump-schemes on the Bouga model; and beyond that limit by settlement schemes, of the model village type, in the rain-lands of the north Central Sudan where the amount of good agricultural land available is almost unlimited.

Ideal remedies, however, that cut straight across the conception of freehold land tenure are apt to be unpopular until the people concerned awaken to the fact that they are suffering from an insidious economic

situation. A considerable period of time may therefore elapse before anything remotely resembling the ideal remedy would meet with any considerable degree of favour.

In the meantime on certain Government pump-schemes north of Khartoum areas have in recent years been redesigned to combat the evils of minute subdivision. The minimum holding of these Government lands is about 10 feddans and remains the property of the State, and dates, citrus, and mango are planted and owned by the State, it being made clear in the lease that inheritance laws apply neither to land nor trees. This development is well advanced at Bouga, Aliab, and Kerma; and at Bouga, the oldest of these modern schemes, the tenants are now well pleased with the arrangements and are rapidly becoming happy and prosperous.[1]

It is possible that in time the better life that will develop on these pump-schemes contrasting with the slowly increasing poverty of the nearby freehold 'sāqiya' lands as they become increasingly subdivided will bring about a realization of the existence of the problem and an understanding of the cause of the increasing poverty.

A final comment is that while the two conceptions (*a*) of freehold agricultural land and (*b*) the emergence of a happy, prosperous agricultural community appear in the twentieth century to be wholly incompatible in a Mohammedan country, yet this was not always so. Under the ancient Bedouin conditions of tribal warfare and constant loss of man-power, populations remained static and the Islamic laws of inheritance produced no problem. It is the combination of peace and the development of a sedentary way of life that has produced the problem.

[1] By way of contrast to the dismal story of this chapter a picture of a tenant's life on a modern type of pump-scheme is given on p. 753.

CHAPTER XIII [1]

EDUCATION

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'Soap and education are not as sudden as a massacre, but they are more deadly in the long run.' MARK TWAIN, *The facts Concerning my Recent Resignation.*

'One should give one's daughters to their husbands maidens in years but women in wisdom.' DIOGENES LAERTIUS, *Cleobolus Sec.* 4.

WERE this a tale only of achievement it would not take long in the telling. The present period of quiet progress is a comparatively recent phase in the Sudan's history; there are no finished structures to admire, but much laborious digging of foundations still to be undertaken. Surveying and planning must, for many years, loom larger than the running of established institutions.

The Problem

Difficulties will doubtless be encountered in resolving the various ramifications of the main problem, but the problem is simple enough in presentation. The few million occupants of this country must look to pastoral and agricultural activities for their livelihood. Such towns as there are, widely spaced and rarely of more than a few thousand inhabitants, are mainly clearing-stations for the produce of flock, forest, and field, and centres for distribution to village shops of the commodities needed by the cultivator and the nomad. Extension of internal markets for agricultural produce, resulting from urban expansion, is unlikely to assume important proportions in the face of the Sudan's lack of predisposing advantages towards industrial development; her geographical position and internal transport problems indicate low prices to the producer for such crops as can find an export market. The problem therefore is the education of a rural population who will largely be engaged in subsistence farming, to bring them to as high a standard of living, culturally and materially, as is compatible with a low income measured in terms of cash, and to enable them to develop a political maturity that will ensure a proper balance with the more vocal urban minority. This is the main task before the educationists. The training of civil servants and professional men and the education of children for town life present comparatively few difficulties and, with increased attention to character-training and inculcation of a sense of citizenship, may be expected to show satisfactory progress. The answer to the charge that much in the following pages is not relevant to agricultural education is twofold. Firstly, as the country, where it is not desert, is wholly pastoral or agricultural, all questions, educational or other, have ultimately a rural significance. Secondly,

[1] This chapter deals with agricultural education in the northern Sudan. Southern education is discussed in the chapters on Upper Nile and Equatoria Provinces.—*Editor.*

agricultural or rural education cannot be properly studied except in relation to the general picture of educational and social development. Hence, without further apology, reference will be made to whatever stepping-stones of progress are considered to have bearing on the main problem, the education of the rural population.

The responsibility of the educationist in facing the main problem is shared by those in charge of research, administration, and economic development. That the Sudan is largely undeveloped, that its agricultural resources offer a livelihood to all who will work, that large landowners are numerically negligible, and that humanism has so far been called upon to make few sacrifices to efficiency are conditions very favourable to the avoidance of errors made in countries where early effort was all towards production and where social problems attained critical proportions before receiving belated attention. The drive for production in this country has hardly begun; no doubt it will be intensified, and rightly so. Extensive and extending manufactured imports are essential to an awakening country bent on taking a place in the civilized world; the necessary income for their purchase must derive from agricultural exports, and that, in a competitive world, implies efficiency in production. Farming on factory lines is to some extent a necessity. There is room and need for large-scale undertakings, but it appears to be possible to associate specialization with a measure of subsistence farming that will give to the individual a degree of security and independence sufficient to promote political stability and a sense of responsibility.

Another avoidable group of errors is that arising from over-stressing the ideal of rugged individualism, with its lack of unified planning and unrestricted freedom to abuse the resources of the country and to ignore the interests of fellow countrymen. By legislation, by sponsoring co-operative enterprise, and by application of scientific knowledge, the scientist and the administrator can minimize the dangers until the slow leaven of education has awakened the individual to a sense of his communal responsibilities, and so far there is no evidence that sanctions can be dispensed with, however highly educated the community. 'Government interference' should be not a bogy but a synonym for planning; 'meeting troubles half-way', so far from being reprehensible, is obligatory on those responsible for the development of a nation; 'dealing with problems as they arise' has been proved a false doctrine where the problems are those culminating slowly out of inadequately guided development in agricultural practice, land utilization, and economic and social structure. The backwardness of the vast majority of the population throws all the responsibility for planned progress, for taking the lead, and for forcing the pace on to the numerically few with modern knowledge at their command, a body to-day contained mainly within the civil services. The impossibility of predicting or, to a large extent, controlling the pace of future developments emphasizes the urgency of pushing ahead with experiment and plan regardless of day-to-day satisfaction with things as they are.

To-day, then, education can be planned against a rural background free from the complications of civilization and commercial exploitation, looking forward to a morrow of sponsored and directed social and economic

expansion. The reader requiring information on the history and present state of the Sudan and its peoples must turn elsewhere. A brief outline of educational developments is all that can be given here, though it is not of course possible to trace all the educational influences of the past nor even to identify all those that are at work to-day. Perhaps something can be read between the lines of this short historical account of schools.

Before the Reoccupation

In the days of the Fung Kingdom nearly every village had its 'khalwa' or Koranic school where religious precepts and a varying degree of literacy were acquired by rote learning. In addition there was a number of more advanced schools for young men intending to become divines, littérateurs, teachers, or exponents of religious law. Sheikhs were sent to Cairo to study at El Azhar and a high standard of contemporary Islamic scholarship was attained. Unfortunately the written legacy of these early poets, writers, and historians of the Sudan was largely destroyed during the Mahdia (1885–98). It is probable that, within the Fung Kingdom, instruction in the elements of religious learning and literacy was given to a greater proportion of the people than is the case to-day.

Some of these old schools survived during the period of Turko-Egyptian rule (1820–85) and a few elementary schools of the 'maktab' type were opened in the towns by the Government. These secular schools paid less attention to religious teaching and more to literacy and arithmetic. The oppressive and corrupt administration drove the Sudan into its unfortunate incursion into self-government, resulting in the strife, famines, brigandage, and pestilence that in the course of thirteen chaotic years reduced the estimated population from 9 to 3 millions. Disruption of the educational system was inevitable and was often wanton, particularly as regards historic documents that might have led to divided loyalties or independent thought. At the time of the reconquest only a few of the old Fung schools had survived or had reassembled, and they survive to-day, as at Umm Duban, Debbat el Fugara, and elsewhere, where boys and men up to middle age may spend an indeterminate number of years memorizing the Koran and the religious teaching of the divines.

Lord Kitchener Builds

Three or four years after the reoccupation (1898) the Government began to provide elementary schools ('kuttab') on the Egyptian model and the simple Koranic school revived to some extent in town and village. Whether consideration was given to the possibility of building on the surviving elements of the indigenous system is not recorded; it is doubtful that such a course would have commended itself to the administration, would have proved practicable if tried, or would have been welcomed by those concerned with safeguarding the traditional learning. Thus there were in existence two distinct types of schools, both common to other Moslem countries. The tradition of rote-learning carried over into the elementary schools, for which the Government was responsible, and the standard of teaching was low.

The Sudan is fortunate in having had the late Sir James Currie as its first Director of Education, 1900–14. One of his earliest steps was the

opening, in 1901, of a Teachers' Training College in Omdurman, to which sons of ''ulema' and influential men were recruited. The next few years saw rapid expansion in teacher training and elementary vernacular schools, the institution of primary schools in which the beginnings of English were taught, and the opening of the Gordon Memorial College as a post-primary and technical school. The foundation of this college was a direct result of Earl Kitchener's far-sightedness and action. The early task was to provide clerks, accountants, and technicians for the essential services, and some departments, notably the Boats and Steamers and the Survey Department, had their own training-schemes from the first. Agricultural training, however, was a notable omission from the plan. Currie wrote in his report for the year 1903: 'I say nothing here about the greatest of all Sudan crafts, Agriculture. I do not consider the time is ripe for instruction in that direction; when the Sudan Experimental Farm, just established, can provide us with accurate data, it will be time enough to consider schemes of Agricultural Education.' The argument carried weight, and its validity is uncomfortably apparent in our present-day experience of agricultural instruction, but Currie never intended the long postponement that in fact was to take place. That his view was not universally shared is attested by a set of drawings prepared by the Public Works Department in 1904 of an elaborate School of Agriculture with farm buildings of a lavish and up-to-date pattern.

The educational policy of the time, little changed since, was the limitation of post-elementary education to the probability of employment in Government service, and the universal spread of elementary vernacular education as rapidly as funds would permit. Although in Currie's time several of the small country towns and larger villages had their elementary schools, there would be little resulting influence on the agricultural population, for such schools are attended, even to-day, mainly by the sons of merchants and officials.

Slow Beginnings of Agricultural Development

Agriculture in the drier provinces, where flood or irrigation is necessary, undoubtedly received a stimulus from the Turko-Egyptian occupation. We know, for example, that Mohammed Ali Pasha pushed the growing of indigo, that Mumtaz Pasha introduced cotton-growing to Tokar, that Hussein Pasha Khalifa, when Mudir of Berber, taught the people to plough, and we can see to-day the few successful and many abortive attempts at diverting flood-water into basins. Similarly, in the early years of the reoccupation, agricultural stimulus depended on individual enterprise rather than a concerted plan, and much interest was taken by some of the early governors. The Agriculture and Lands Department, as it then was, seems to have been mainly concerned with the disposal of land to any who would buy, a policy that raises eyebrows to-day, but which in the poverty-stricken and depopulated country of the time, when ostrich feathers, ivory, shells, and gold figured large in a pitiable list of exports, was justified by the pressing need for revenue. A small and very slowly increasing handful of Agricultural Inspectors was over-busy with assessing lands for sale, revenue-hunting, and starting experimental farms in

face of the difficulties arising out of the absence of any skilled labour or local knowledge. Though some of them, such as G. H. Nevile, had ideas that have not since been bettered for spreading agricultural knowledge and for the stimulation of rural communities, these men had neither time nor staff, nor were they given encouragement, to carry them out.

Some Milestones

Among the landmarks of educational and agricultural development of these early years must be mentioned the repeated petitions from Rufa'a and Khartoum for girls' schools in 1906 and the opening in 1907 of a school for girls at Rufa'a by that progressive stalwart of Sudanese education, Sheikh Babiker Badri.

In 1907 and 1908 eight boys of Dervish origin, who had been sent to Egypt after the conquest and had since completed a course of instruction on the farm of the Khedivial Agricultural Society near Tantah, returned to reinforce the meagre agricultural staff, and, after further local training, to give, in most cases, invaluable service to agriculture for many years.

The year 1911 saw the formation of a separate Department of Agriculture and Forests, followed in 1912 by the transfer from it of experimental work to the Education Department as part of a policy advocated by Currie of bringing all research activities under a unified organization. 'The foundation of a School of Agriculture', wrote Currie, 'is the next step, again following Indian precedent, and it ought to be started next year.' The next year saw many activities at the reorganized Shambat Experimental Farm, including the appointment of a Keeper of Ostriches, but no School of Agriculture.

Agricultural Development Accelerated

The outbreak of war in 1914 heightened interest in agriculture and induced the Government to give more scope to the Department of Agriculture and Forests. After the pacification of the country at the beginning of the century the cultivators, assured that they could reap where they had sown and could eat what they had harvested, had resumed their customary farming, but the suppression of slavery had in some places been something of a setback to production, the population was increasing rapidly, internal transport lines were long and difficult, and regional crop failures frequently resulted in local famines calling for official action. War-time inflation raised the price of agricultural products to several times its pre-war level. An early step was the recruitment of more British staff and the installation of pump-irrigation schemes to supplement the water-wheels at some half-dozen places in what is now Northern Province. Instituted as anti-famine insurance, these schemes remained to exert an agricultural and social influence that is hard to assess. In their respective districts they brought a material security to supplement and complete the political security achieved 20 years previously. They also brought British personnel into closer daily contact with the peasants than had ever before been attempted, for each scheme had its Inspector giving his whole time to his few hundred cultivators and training them in the ways of providence and better technique. It is fashionable to-day to look askance at such

direct administration, but it is only fair to consider to what extent the practicability of devolutionary proposals is due to the moral and technical training given by these Inspectors in the face of pioneer difficulties and misunderstandings.

The Berber Agricultural School

Certainly these officials achieved more for agricultural education, albeit under another name, than the Berber Agricultural School, opened in 1916 by the Education Department in collaboration with the Department of Agriculture and Forests which lent an experienced Egyptian and a Sudanese agriculturist. It was attached to the Berber Elementary School, and gave a 2-year course to boys who had completed three years in any elementary school in the province. Its object was to provide a practical training for those destined either for purely agricultural pursuits or for agricultural employment. One or two who found employment with the department have given excellent service. The boys were made to work hard, spending most of their time in the field and taking only one month's holiday in the slackest time of the year. No fees were demanded, and a pupil might take whatever profits accrued from the cultivation of his own rood. The comment of a Sudanese Inspector of Schools recalls Pepys on Christ's Hospital: 'They look very well with their straw hats and white gowns'; and, less happily, 'The Sol of the School goes every morning to the farm to see the attendance of the boys and to inflict any corporal punishments required.' A proposal to open a similar school at Shendi in 1918 came to nothing. The attendance at Berber was never large and dwindled rapidly when it was realized that prospects of employment were few and that boys were expected to return to work on their fathers' farms. A measure of financial stringency in 1923 was made the occasion for closing the school. Its failure gives point to the argument advanced later that schools can achieve little *in vacuo*; they must be part of a scheme of community education. In this case there was no cultural and probably little technical continuity between the boys' schooling, excellent in itself, and the environment to which they returned. That education was of little value, was in fact undesirable, to boys returning to peasant farming, was the view strongly held by the cultivators themselves, who would send a boy to school only in the hope that he might obtain employment, never with the expectation that he would return to cultivate. This attitude is nearly as strong to-day.

More Milestones

The first world war interrupted the rapid increase in number of Government schools. The anti-British agitations of 1921–4, conducted by an inspired minority in a few of the larger towns, and the institution of the Indirect Rule policy in 1927, gave rise to doubts of the wisdom of pushing ahead quickly a modern type of education, and support was to some extent transferred to the indigenous Koranic schools or 'khalwa'. Thus, although the post-war decade saw rapid economic development, educational expansion was largely restricted to the Gordon Memorial College, which had 134 pupils in 1920 and 555 in 1930.

Girls' education was reinforced by the appointment of a British woman in 1920 and has since expanded steadily, though quantitatively lagging far behind boys' education.

An important expansion at this time took place in Agricultural Research and Field personnel, most of the latter working in close contact with the cultivator and thus effecting agricultural education in the manner already described. The dissolution of the Military Training School in 1924 gave the department a batch of educated young men, selected largely for personality, some of whom buckled down to their new work and are valuable public servants to-day.

The benefaction of Hashim Bey Baghdadi led to the opening, in 1924, of the Kitchener School of Medicine for training Sudanese doctors.

The Winter Committee

One of the results of the financial crisis of 1931 was unemployment, particularly among the products of the primary schools and the Gordon Memorial College, and it became apparent that these youths were, by their education, unfitted for anything but Government service. This led to the setting up of the Winter Committee of 1932, whose function was '(*a*) to review the educational system of the schools of the northern Sudan and to suggest what steps, if any, are necessary to ensure that the system and training are adapted to the practical needs of the country; (*b*) to consider what steps can and should be taken in the immediate future to provide training for Sudanese in the administrative and technical departments of the Government in order to increase their usefulness and provide openings for their practical advancement'. The committee was faced by an examination-ridden system; elementary schools divorced from the life of the productive country-side, with teachers cramming to get results and ineffectively following inadequate instructions to teach new subjects in which they themselves had received no training; primary schools concentrating on English and giving little education suitable to the majority who failed in the scramble for a place in the Gordon Memorial College. This last was by now called a secondary school, though it was short of matriculation standard and at the half-way stage labelled its boys clerks, accountants, teachers, kadis, engineers, or doctors. The committee reaffirmed Currie's policy of widespread elementary education, and attached 'importance to the introduction of a rural bias'. It asserted that the primary schools should no longer be regarded solely as feeders to the Gordon Memorial College, and that the latter should not be regarded solely as a feeder to Government service. It also made rather tentative mention of the desirability of opening a farm school, and of technical education in general.

Reform of Elementary Education

Reforms must begin at the bottom, and the first logical step was attention to the training of elementary school teachers. The transfer in 1934 of the Elementary Teachers' Training College from Khartoum to rural surroundings at Bakht er Ruda has since proved, under the leadership of its first Principal, V. L. Griffiths, to be the most important single step in

educational progress in the last 40 years. It was largely owing to the faith and perspicacity of Sir Hubert Fass, then Financial Secretary, that this move was carried out despite the serious financial difficulties of the time. The introduction of a 'rural bias' cannot be achieved overnight or on the recommendation of a committee. Unlike Arabic, religion, or even, to a much less degree, arithmetic, history, and geography, it has no tradition behind it; teachers have no conviction that the study of rural affairs is either interesting or worthy. The strength of tradition in the East is nowhere more in evidence than in ideas of education; it is no small task

FIG. 72. A 'khalwa' in Khartoum Deims (*photo V.L. Griffiths*).

to build up new traditions. The surroundings helped; so too did new methods of teaching old subjects, hitherto learnt by rote, and the stimuli of art, handwork, school societies, and camps. An Agricultural Inspector was seconded to guide the teaching of natural history, elementary science, agriculture and hygiene, and a Young Farmers' Club soon became the medium of introducing the pupil teachers to the economics, interest, and drudgery of crop production. The sympathy of older teachers was enlisted by bringing them in on short courses, with a measurable degree of success. There are to-day many elementary schools wherein the teaching is stimulating, and a few which successfully relate their activities to local conditions of life.

The course of this Elementary Teachers' Training College has recently been expanded to 6 years, of which only the last 2 are vocational. This permits entry to the vocational years of boys who have completed their course at reformed intermediate schools, hitherto called primary schools. Otherwise boys are selected from elementary schools and spend six years

at Bakht er Ruda. In either case selection is on Governors' recommendations, with a qualifying examination, and boys are recommended on a basis of tribal or local acceptability to the district in which they will be required to teach. Undoubtedly by this system, by propaganda, by some realization of future trends, and by the Government's insistence on schooling for future local leaders, the rural population is in some districts losing its fear of education and is even beginning to appreciate its value other than as a route to employment. The more sophisticated areas are now clamouring for schools, but the backward areas are vastly greater and the need for education is often greatest where the demand is least. The associated problem of how to bring this comparatively expensive education within the reach of scattered communities is partially solved by the institution of boarding-houses at rural elementary schools and some intermediate schools. Government-assisted 'khalwa', and sub-grade schools—a modernized 'khalwa' with a partly trained teacher—meet the demand for literacy in places where elementary schools cannot yet be justified, and might become a valuable part of community education schemes.

The School Garden

That country schools should have gardens or small farms is no new idea, but the value of this type of activity has rarely been fully examined. This question has recently been the subject of much thought and experiment. It is easy to insist that each school with facilities to do so should have its cultivation; it is not difficult to make the school garden look tidy and praiseworthy to the casual visitor and the subject of a pretty paragraph in the annual report. To make it serve its educational purpose, however, is another matter. If the teacher drives the boys to efficiency and takes all the initiative upon himself they learn little except possibly a distaste for the work; at the other extreme are the dangers of slackness, acceptance of low standards, and results that discredit the school in the eyes of the neighbourhood. A symptom of the first type of error is unnatural tidiness and absence of mistakes; the second type is even more self-evident. Running on a club system is desirable and has additional education value more important than the acquisition of a little horticultural knowledge. Boys must have their own plots or at worst share with not more than two partners. Freedom of cropping and a share in individual profits are other essentials. In the background is the teacher, guiding and inspiring, stimulating interest and taking opportunity of teaching the lessons of co-operation, perseverance, responsibility, and planning ahead. Too often his lack of expert knowledge prevents his effecting any improvement in technique, and is responsible for the low standard of performance. If conditions are favourable there may be opportunity of running, in addition to the boys' plots, a school plot to make some simple demonstration of local interest, such as the use of copper carbonate in controlling smut, and this, if successful, enhances the local prestige of the school. Such schools are a useful medium for dissemination of propaganda on matters like locust control that require the understanding and co-operation of the villagers. Those who question whether the value

obtained from the attempted introduction of a rural bias into country schools is worth the expenditure of effort should consider the importance of the attendant learnings mentioned above and should reflect that even if the country boy, with a knowledgeable cultivator as father, does not learn anything new, at least there is a chance that his inherent rural interests may survive and that his education may enhance his interest in his environment and not alienate him from it. This chance will be increased if the teacher can be given some agricultural training, and maybe through schools agriculture will acquire a share in the prestige that traditionally attaches only to literary subjects. There are signs that nature study and elementary science are already acquiring a prestige of their own, just as domestic duties in the home are acquiring a prestige from the teaching of domestic science in the girls' schools.

A full elementary school has four classes of fifty boys and is regarded as fortunate if it has four teachers. Six teachers should be accounted the minimum for an effective rural school. The newly introduced subjects and new methods of teaching old subjects involve time and care in preparation, improvisation of apparatus, and search for material and local knowledge. There are also football and other games, the boarding-house, the cultivation, perhaps poultry and other livestock, clubs and societies to be unobtrusively guided, school dramatics and public occasions, after-care and the Old Boys. In addition the ideal schoolmaster is expected to keep in touch with the boys' fathers and with local affairs and to act as village counsellor when called upon, and as interpreter of Government policy and propaganda. His school must achieve an academic standard that will obtain good results in the competition for places in the intermediate school. Sheikh Mohammed Hamad Nasr came near to doing all this at ''Abassiya', and the country suffered grave loss by his early death in 1939. This school at ''Abassiya' also demonstrated the value of catching a district at a period of economic development, and showed how valuable can be the right kind of support from the nearest Agricultural Inspector and District Commissioner. To-day there are not more than six rural schools of this calibre. Their multiplication, coupled with adult education, is urgently required.

The Intermediate School

Reform of the intermediate schools is proceeding on similar lines. Elementary science has been added to the curriculum, and, though drawing was already in the time-table and carpentry had been tried unsuccessfully in the past, the introduction of art and handwork by modern methods may also be accounted an innovation. More attention is now given to the training of teachers, to revision of teaching methods and of matter, to out-of-school and character-forming activities, and to relating the schools to the life of their respective districts. A rural intermediate school was opened at Dueim in 1936. Dueim was selected in order that the staff of Bakht er Ruda, 2 miles away, may give attention to the school until the experimental period shall be over. It has, of course, a boarding-house and receives selected country boys from as far afield as Kordofan and Northern Province, the basis of selection being assurance of subsequent

rural occupation. The type of education given is designed to suit boys returning to rural districts to take part in local administration or in agricultural life, whether directly or after subsequent education at post-intermediate level. The demand for this type of school will increase rapidly as more country boys, largely through the boarding facilities now available at most country elementary schools, receive elementary education. Plans for opening similar schools are retarded not only by the present war but also by the time needed to build up a cadre of suitably trained teachers. The incidence of education in the past has naturally meant that nearly all officials and students in post-elementary schools to-day have had an urban upbringing, and few of them train readily into rural workers.

The Junior Secondary School

Entry into the secondary school, with its prize of Government employment carrying pay and status difficult of attainment otherwise, is the subject of such keen competition that intermediate school education, despite reforms, will be largely directed to the attainment of examination successes. In the past the most unfortunate product of the Sudan's education system has been the majority of intermediate schoolboys who failed to gain a place in the Gordon Memorial College, and, pending the fruition of reforms, this is still so to-day. Many obtain minor Government employment, but those who do not, which in times of depression is nearly all of them, find that their education has divorced them from indigenous ways of earning a living rather than equipped them to take their place more competently among their less educated fellows. It is hoped that the reforms in the intermediate schools will to some extent meet the situation, and that further improvement will be obtained by the plan described below, which owes much to E. N. Corbyn, Director of Education in 1927. Competition for the secondary school takes place at the end of the 4-year intermediate school course. A further 2 years' education is now available for those intermediate schoolboys who either do not wish for full secondary education or have failed to qualify for it. These 2-year post-intermediate schools are called junior secondary schools. Some are well established, others are yet to be started. Free from the pressure of examinations, they permit a boy to give more thought and less hurry to his general education and they also introduce subjects related to the environment of his future life and of practical use in his probable profession. One or two of the schools are attached to departments and are specifically vocational, such as the Posts and Telegraphs School, the post-intermediate section of the Atbara Technical School, and the final years of the Elementary Teachers' Training School. Others will be more general but biased towards local needs, like the Omdurman Junior Secondary School which gives much time to commercial subjects. The increasing realization of the importance of providing an education suitable for country boys led to the inclusion in the plan of a rural junior secondary school which was opened at Dueim in 1942. This school gives much time to agricultural activities, using them as a peg on which to hang a general education for rural life.

By no means all intermediate schoolboys wish to proceed to these

schools; many, having failed in their ambition to get into the secondary school, have no desire for further education, and it is difficult at present to recruit to the rural junior secondary school a full entry of boys who are assured of future rural employment. This situation may be expected to change as the incidence of education falls more rurally. Like the rural intermediate school, it is a boarding-school and was sited at Dueim to permit co-operation of its staff with that of Bakht er Ruda. Although in its agricultural activities it is assisted by staff of the Department of Agriculture and Forests it is no sense a vocational school. As the mis-

FIG. 73. Teachers' Training College at Bakht er Ruda. Bamboo pipe playing—a number of boys are keen (*photo V. L. Griffiths*).

apprehension is commonly held that specific agricultural training is given at Dueim or Bakht er Ruda, it is perhaps advisable to restate the functions of the various schools there and to emphasize that teacher training is the only vocational training there given.

At Bukht er Ruda

Dueim Elementary School. Serves the town, but run as a rural school. Has a boarding-house. A double school used largely for educational research and teaching practice. Has school gardens.

Elementary Teachers' Training School. Equivalent to a rural intermediate school with two subsequent years of vocational training. Has cultivation. Young Farmers' Club, &c.

Refresher course for elementary and intermediate teachers.

Post-secondary students under training as intermediate teachers.

At Dueim

Rural Intermediate School, with boarding-house, cultivation, &c.

Rural Junior Secondary School, all boarders, much time given to agricultural activities.

Although there is no vocational agricultural training given at the above schools they together form the centre of education designed to influence agricultural communities. Their attendant agricultural activities will doubtless become more business-like and therefore more valuable when it is possible to give agricultural training to selected teachers. It is likely, however, that vocational agricultural education will remain in the hands of agricultural specialists with a bent for education rather than in the hands of educationists with a bent for agriculture, and this is as it should be.

Technical Schools

The absence of vocational agricultural training during all these years is only part of the general neglect of technical education that has existed since the beginning of the century when instruction in the crafts made a fair start in the Gordon Memorial College. Since leaving the College buildings it has been sadly outstripped by literary education. Although the new higher schools provide professional training at a high level, there are few facilities for training the intermediate or secondary school boy into a master-craftsman. This leaves a serious gap in a country where indigenous standards of craftsmanship are deplorably low and where tradition accords respect to high rank and reputation for learning rather than to industry and skill. Apart from the wholly or partly vocational schools already mentioned there are the small but excellent Omdurman Technical School for ex-elementary schoolboys, and the post-elementary section of the Atbara Technical School, which is run by the Railways Department. Modern technology has as yet touched the Sudan too lightly for many boys to have developed a natural bent towards practical hobbies, and it is not remarkable that competition is all towards the respected black-coated professions when the latter offer a safe, more remunerative, and less arduous career. This is in contrast to conditions in America or England where an enterprising boy knows that as a master-builder or skilled mechanic he can earn twice as much as a clerk and can satisfy his desire to create and to do things well, and is rightly considered the better man. Government action has done nothing to change tradition in this respect, and it is chastening to reflect that the position to-day is the same as in 1906 when Currie, commenting on the general terms offered to clerical staff, wrote: 'I earnestly hope that corresponding liberality will be shown, in the matter both of pay and of pension, to men with technical training and to skilled artisans. It is idle to talk to the natives of the Sudan about the importance of such a training if at every stage we give higher recognition to the petty clerk who in comparatively comfortable surroundings typewrites and copies letters between the hours of eight and one.'

After the Winter Committee there was much discussion of the advisability of starting a farm school, largely as a means of opening an alternative profession to boys who might otherwise increase the number of educated unemployed. As few would have private opportunities of entering farming, the project involved the necessity of a land settlement scheme and called for careful nursing in the early stages. With the return to prosperity and decrease in unemployment the project was dropped. It

was held inadvisable to make the beginnings of so important a social and political venture with town boys who had failed in the competition for other employment. Perhaps it is a pity that a beginning was not made on a small scale, to provide experience against the day when a return to unemployment conditions may necessitate urgent action without time to consider pitfalls. Land settlement proposals have again been raised to meet the needs of rural junior secondary school boys, and it is to be hoped that the war-time difficulties that stand in the way of making a small beginning will shortly be overcome. Essentials to the success of any plan to settle educated young men on the land appear to include the possibility of making a cash income comparable to that of a junior Government employee, opportunities for social contact with other educated people, and guidance in developing the variety of home amenities that enable farm life to compete in attraction with the lure of the town.

Non-Government Schools

Most non-Government schools in the northern Sudan are urban, but mention must here be made of the school at Gereif, near Khartoum, run by the American Mission. Started in 1924 it gave a modified secondary type of education, including instruction in agriculture. It had an enterprising farm, with a herd of cattle deriving from imported Friesian bulls, and doubtless much of the instruction, particularly in horticulture and dairying, was potentially valuable. Some Gereif boys who subsequently found opportunity of using their knowledge have done well in either Government service or private employment. Perhaps the school's chief difficulties were firstly that, not being a Moslem institution, it did not attract the type of boy who had opportunities for private farming, secondly it was not an assured route to Government employment and agricultural education *per se* was not much in demand. It closed in 1938 in favour of an experiment in village improvement. The necessary staff for this new venture has unfortunately been delayed by the war. Other missionary effort in the Moslem Sudan is restricted to special urban needs and has no bearing on rural problems. In the pagan areas, where missions are various and widespread and Government schools are few, the indebtedness of agriculture to education is not always apparent and the effect of the schools on rural development is not always perceptible. Discussion of southern education, however, is to be found not in this chapter but in those on the provinces of Upper Nile and Equatoria.

Professional Training

It will have emerged from the foregoing pages that only a few of the Sudanese staff of the Department of Agriculture and Forests had had any agricultural training prior to their employment. Some branches of the research service had apprenticeship facilities, but generally the young employee had to learn his job as he went along and the training he received depended much on the temperament and preoccupation of his seniors. A fair proportion did well, but many, being town bred, suffered the boredom born of ignorance, and their lack of interest in their work increased

as prospects of promotion faded. The revision of the treaty with Egypt in 1936 pointed to the need for expediting the training of Sudanese for more responsible posts, and a policy of higher professional training was drawn up. Schools of higher instruction were planned by the Education Department or the appropriate professional departments, and in 1936 His Excellency the Governor-General, Sir Stewart Symes, ordered that post-secondary training in veterinary science and in agriculture be started without further delay. A class of students, recruited from boys who had done well in the science section of the secondary school, took a general course in science at the Kitchener School of Medicine in 1937 at the end of which three boys were selected for veterinary training and six for agriculture. R. K. Winter, Director of Education 1932–6, and the late M. A. Bailey, head of Agricultural Research from 1931 to 1938, had drawn up proposals for a School of Agriculture that was to operate as a modest adjunct of the Gezira Research Farm at Wad Medani, where buildings for the school were erected in 1937. The school was not destined to occupy these buildings, however, for plans were changed after the visit of the De la Warr Commission early in 1937.

The De la Warr Commission

This commission, under the chairmanship of Lord De la Warr, was a body of educational and political experts sent from England to make recommendations regarding the development of higher education in East Africa. The Sudan Government invited them to perform a similar service for the Sudan on their way home. Their main recommendations were concerned with the institution of professional higher schools in a manner calculated to lead to the development of a University College. In conformity with the intention of Lord Kitchener the nucleus of this higher education was to assume the name and to occupy the buildings of the imposing and well-situated Gordon Memorial College, and a magnificent set of new buildings was erected for the secondary school at Wadi Saidna, a rural site 15 miles north of Omdurman, followed by the building of a second secondary school in 1945 at Hantūb across the river from Wad Medani. The reason for this much-debated move of the secondary school into the country was not so much an intention of introducing a rural bias into secondary education as a hope that away from urban distractions boys and staff might develop more fully the corporate life of a big school, after the pattern of the great public schools of England. All boys at the secondary school were to take the same general course, specialization becoming a function of the higher schools. Thus general science became a subject for all, the old science section was abolished and a post-secondary school of science was instituted to meet the needs of those going on to agriculture, engineering, medicine, science teaching, and veterinary training. In 1938 for the first time the top half of the fourth-year classes sat the Cambridge School Certificate Examination, and 20 certificates were obtained, the number rising to 72 in 1944. There are those who assert that concentration on the examination is a strain and adversely affects the education of the boys, and that it should not have been introduced until standards had risen to a stage when the boys could take it in their stride. Greater heed,

however, was paid to the arguments for expediting attainment of professional standards in the higher schools, and for this end School Certificates are unquestionably necessary.

The Gordon Memorial College Reconstructed[1]

With the exception of the Kitchener School of Medicine the various higher schools shed their departmental identities and were combined into a corporate body in 1944, under the name of Gordon Memorial College. The President of the College Council was His Excellency the Governor-

FIG. 74. Gordon College, Khartoum, when it was a Secondary School. Sept. 14, 1929, at 9.45 a.m. The building now houses Gordon Memorial College in process of becoming a University College (*photo V. L. Griffiths*).

General, Sir Hubert Huddleston, and Dr. J. D. Tothill was appointed the first Principal. At the inaugural meeting of the Council 'The Aims and Policy of the Gordon Memorial College' were set out in the following statement:

'The functions of the Gordon Memorial College are teaching and research. The value of research is not only intrinsic: it should also assist teaching in various ways. It should attract good staff and help to maintain its quality; and it should influence the students—through their contact with those engaged in it—towards acquiring the scientist's and scholar's objective attitude to knowledge, a realization of the social and economic problems of their country, and a proper assessment of solutions.

'The College seeks that its students should acquire not only a high standard

[1] In December 1945 the Gordon Memorial College Council decided to associate with London University for degree-granting purposes for the University College period of growth towards full University status. This association has now been achieved and plans have been made to commence the first London degree course in January 1947.—*Editor*.

of academic and professional knowledge, but also those qualities of mind and character which are necessary for good citizenship and professional competence. It tries to develop in all its students cultured and balanced minds, objective interest in work and study, a sense of responsibility, and a genuine desire to serve the community. Academic attainments have little worth without a moral basis and a social sense.

'These aims can be obtained partly through good curricula, adequate apparatus and libraries, and wise teaching (such as can produce in the students not only knowledge, but also the character and culture obtained through the understanding of the values and traditions of great professions and of research). But in addition it is necessary, and should be the care of the staff, that the students' general environment—intellectual, moral, social, and material—should be sound and stimulating.

'The College also seeks to encourage and as far as possible to take part in schemes for the advancement of education outside its walls, whether in the form of courses of study, or by means of libraries, lectures, museums or otherwise.

'The College aims at the status of a university college in the near future, and hopes ultimately to attain full university status. It has much to learn from existing universities, and should follow their lead in many ways, and seek their help. Owing to the local conditions, however, we should not adopt their features without scrutiny; nor fear to be different, provided we maintain our high aims.'

The establishment of the college in its new form will always be associated with the name of its first Chairman of Council, Sir Douglas Newbold, by whose early death a few months later the college lost an ardent and scholarly counsellor.

There are two factors limiting the number of students entering the Gordon College; one being the present absorptive capacity of the various professions, the other, which is at present the more operative, being the output from the secondary schools of a sufficient number of boys capable of making good use of further education. The number attaining School Certificate is insufficient to offer an adequate selection of entrants for the higher schools, of which agriculture is a relatively small part, as shown by the following intake figures:

	1944	*1945*
School of Science . .	28	27
School of Arts . . .	34	45

The School of Science prepares students for the Kitchener School of Medicine, the School of Engineering, the School of Agriculture, Khartoum Veterinary School, and the Institute of Education. From the School of Arts most students proceed to the Institute of Education or the School of Administration.

In addition the School of Law recruits a class of fifteen students every fourth year. Entry to these schools is not necessarily restricted to those gaining Government scholarships. A student not desirous of Government service, of adequate academic standard, and willing to pay fees is welcomed at some of the schools, particularly so at the School of Agriculture. As regards fees, the policy is the same for all schools above the elementary level: sufficient free places are awarded to ensure education for the brightest boys and an adequate flow of the best brains into civil services. Thereafter, fee-paying pupils of adequate standard are accepted to the capacity of the schools. The fee collected is a compromise between the true average cost of educating a pupil, the cost involved in accepting an additional pupil, the fees charged for comparable education elsewhere,

and the parents' ability to pay. Full fees at the School of Agriculture, covering board, medical treatment, and various other privileges, are at present £E.55 per annum.

The School of Agriculture

(*a*) *Diploma Course.* Shambat, 4 miles north of Khartoum, was finally selected as the site for the School of Agriculture. There were several reasons for preferring it to Wad Medani, including accessibility to corporate and cultural facilities deriving from proximity to the incipient University College. The school started in 1938 in makeshift quarters with its first entry of six students, and occupied an excellent new building at the beginning of 1940. It now offers six scholarships for new entrants every other year, an average output of three per annum being commensurate with the Department's absorptive capacity for this type of recruit.

Students are selected for the School of Agriculture after completing a 2-year course in biology, physics, and chemistry at the School of Science. Thus with their 3-years' course at Shambat the students have 5 years' post-secondary training. In view of the impossibility of predicting future developments those responsible for designing the course have not attached undue weight to the present scope of duties of the agricultural official and have borne in mind that as the agriculturist, whether farmer or official, is likely to be isolated, with other experts not easily accessible, he needs to be something of a Jack of all trades. The curriculum therefore is at least as comprehensive as those of agricultural schools elsewhere. The subjects to which most attention is given are agriculture, agricultural botany, agricultural zoology, pedology, biochemistry and nutrition, microbiology and genetics. Because of its importance in irrigation much time in the field is given to surveying; and agricultural engineering includes hydraulics related to irrigation and drainage, the construction of simple buildings, and the elements of mechanical engineering related to engines, pumps, and farm implements. Experimental method and statistics, forestry, horticulture, farm book-keeping, veterinary hygiene, and a short course in public health all have their place. The courses are still in a formative stage and lack of information relating to Sudan conditions is frequently an embarrassment. To some extent the war has interfered with their improvement, notably in mechanical engineering.

Great importance is attached to giving the students familiarity with the principal tools of their trade, namely the labourer and the peasant cultivator. Because of the background of the present generation of educated Sudanese it is difficult to over-estimate the importance of familiarizing these future agriculturists with the problems of the people with whom they will be working, and of imbuing all higher school students with a spirit of service, sympathy, and responsibility towards their less educated fellows, Social and economic aspects are dealt with in the agriculture lectures, but more important is an annual camp for first-hand study in some remote area for 4 or 5 weeks, and this, in a country showing such agricultural variety, has additional value if the site is varied from year to year. During the war years students have helped to meet the need for additional personnel by working part-time in stimulating production in

the areas of rain cultivation, and this has developed to a striking degree their personalities and their interest in their profession and their country. Duties of this kind will normally occupy part of the long vacation. The lack of any preliminary agricultural knowledge in the majority of the students makes it advisable to make the first year a comprehensive introduction, not leaving some aspects of farming untouched until the third year, when little time is left for directed observation. Thus from the beginning some of the pre-breakfast periods are labelled 'field biology', wherein students make supervised observations of pests, diseases, and other field phenomena that would otherwise not be encountered until later; and first-year agriculture lectures include general matters as well as first principles. Attempt is made to make the course not merely a technical training but liberally educational; it is hoped that a student may acquire his knowledge with appreciation and his technique with enjoyment. There should be at least as much spiritual satisfaction in a farmer's life as in that of any other artist, and the cultural value of a subject or profession depends not so much on the subject itself as on how it is appreciated and studied, whether it be living agriculture or dead languages.

A common criticism of educated Sudanese is that they despise manual work and are incapable of doing it. 'The dignity of labour' is a phrase more popular with those who have no intention of callousing their hands with anything heavier than a tennis racket than it is with those who sweat for a living. Ambition to rise from executive toil to administrative ease is by no means peculiar to the Sudan. If it is true that Eastern tradition, not far removed in time from slavery, does not properly apportion respect between the dignified and the practical, it is well to consider to what extent the example of the British official, from the nature of his position in this country, has reinforced this attitude. Instruction in manual work is not normally the function of agricultural colleges, which assume or insist on practical experience before a student is admitted. The lack of facilities in the Sudan for working as farm pupils under progressive farmers makes it necessary for the School of Agriculture to take steps to minimize this serious deficiency. Standards of proficiency are set in all skilled or semi-skilled agricultural labours; a specified number of these standards is attained by a student before he sits the annual examination, and a prize is awarded annually for practical proficiency. Members of the staff give informal coaching out of school hours, and facilities for practice are provided. The students fully realize the importance of this aspect of their education. A most important and most difficult task of the educationist in the Sudan is to inculcate personal standards, to inspire pride not in position and status but in ability and performance, and performance not for praise but for self-satisfaction, which in turn should be the result of informed self-criticism.

The standard aimed at is that of a pass degree of a British university,[1] and the best students attain this standard in the various branches of agricultural science, but deficiencies in their general education, home background, capacity for reading, and the lack of contact with a know-

[1] As a result of association with London University a Diploma and a degree course are being offered as from Jan. 1947.—*Editor.*

ledgeable farming community and facilities for practical pupilage prevent them at present from being comparable with a British agricultural graduate. Like most of the other higher schools, the School of Agriculture is aiming at standards that will bear international scrutiny. At present not all the students for whom post-secondary education is desirable can attain these standards and those who fail only narrowly to attain the professional standard and who are otherwise satisfactory and are benefiting from the course are not rejected nor regarded as failures, but are not awarded diplomas. The standard of the diploma is jealously guarded. An occasional outstanding student may be sent abroad for further studies, and this would apply particularly to men destined for research. Examinations are held at the end of each of the 3 years, and at present external examiners are drawn from outside the school but within the Sudan. When the time comes to seek external recognition, lack of the necessary special knowledge of Sudan agriculture will be a difficulty to the external examiner from abroad, and his task of arriving at an estimate of the standard attained would be facilitated if the students, on leaving the School of Science, could take an external university examination in the pure sciences at intermediate level. The next few years should see steps of this kind being taken towards university college status [1]

(*b*) *Courses for Teachers.* With a 3-year course and alternate-year entry the School of Agriculture has, in alternate years, only one class in residence. In those years a class of students under training to teach science in rural intermediate schools comes to Shambat for a general course, learning something of agricultural matters, and finding a practical application of subjects studied in the School of Science. This course, though sketchy, has some value in supplementing urban with rural interests, and it is hoped after the war to make it more thorough for selected teachers. Selected elementary school teachers will also, it is hoped, be provided with a suitable course at Shambat to enable them to conduct school farming projects with more technical skill.

(*c*) *Research.* The main task of C. W. M. Cox, Director of Education 1937–9, was the planning of the higher schools. He saw that, from the nature of the country, the School of Agriculture was in the long run likely to be the most important and perhaps the only one capable of much numerical expansion. He did much to gain acceptance for this view and ensured that the school was started, as regards staff and buildings, on a scale not unworthy of its potential importance. In the original planning of the school it was apparent that, to make teaching possible, much work would have to be done in co-ordinating the agricultural knowledge scattered throughout the country, and that there would be many gaps to be filled by original work on the part of the staff. The value of research work *per se*, as a vitalizing influence on the staff, as a necessary background to study, and as a proper function of a centre of learning, was recognized

[1] Resulting from the decision to link with London University, referred to in the footnote on p. 237, some changes are being made designed to improve standards and to broaden the cultural basis. As from January 1947 a preliminary year at the sixth-form level is being introduced until such time as this work can be given in the secondary schools; a degree course at the School of Agriculture is also being introduced in addition to the Diploma course.—*Editor.*

from the start and was reaffirmed as an essential part of the life of the Gordon College in its statement of aims. Inevitably the war, with its demands on man-power, has caused postponement, but it is already possible to record progress in research on cattle management and nutrition.

(*d*) *The Two-Year Junior Course.* Important among the items postponed is the institution of a junior course, of 2 years' duration and very practical in content, suitable for rural junior secondary school and similar boys needing technical training for employment or for land settlement schemes. It is preferred that pupils should enter such a course not straight from school but after 2 or 3 years' experience of life. This will enable them to make a better informed choice of profession, will enable employers to select their men at a more proven stage, and will allow that students come to their studies with a more mature intelligence and seriousness of mind.

(*e*) *The Special Course.* Some leading authorities on education advance arguments, similar to those expressed above, in favour of a break between secondary and higher schooling, but the possible ensuing imperilment of academic standards makes the adoption of such a proposal unlikely at present with the type of student who is aiming at high academic qualifications. There is, however, another class of young men whose trained services are required. The present limited field of selection makes for the acceptance into the higher schools of a proportion of boys who are not otherwise outstanding among their fellows, and concurrently the present difficulty to the majority of obtaining a School Certificate excludes from the higher schools some of those who have natural qualities of leadership. It is proposed that as from January 1947 scholarships to the Degree and Diploma Courses should be awarded only to those who are personally as well as academically sturdy, and that there should be another course for ex-secondary school boys, selected after proving their worth a year or two after leaving school. This course, referred to as the Special Course, would not attain such high scientific standards as the Diploma Course, but would be equally thorough, and those taking it would be capable of competing on equal terms for field service in the department. The best of the younger officials already in the service would be enabled to take a course of this kind and thus to bridge the gap between the generation to whom higher education has become available and those born a few years too soon for it.

In summary, the courses at Shambat, either in being or planned and held up by the war, are as follows:

1. London Degree Course, post-secondary and post-school of Science.
2. Gordon College Diploma Course, post-secondary and post-school of Science.
3. Special Course, post-secondary, selection 2 or 3 years after leaving school.
4. Junior Course, junior-secondary standard.
5. Course for selected rural intermediate teachers.
6. Course for selected elementary teachers.

To discuss the part that the school may play in the development of the

agriculture of the Sudan, to review the vast branches of knowledge that are yet uninvestigated and untaught, and to speculate on the possible effects of this new educational venture are temptations that must here be resisted. Research workers with time to teach, teachers with time for research, multiplication of activities of the school farm, a library and a museum worthy of the subject, are all part of the hopes that may be realized during the next few years, and lying over all is the hope that ex-students of the school may worthily carry their share of the responsibilities and tasks that lie ahead.

Extension Work

The type of official produced by the courses outlined above is expensive in training, in salary, and in pension. His number is inevitably limited and is a meagre figure on the map of the Sudan. To reach the individual cultivator there must be a large body of intermediaries, headmen or headmen's agents such as those now becoming an important part of the administration of large irrigation schemes. These are best trained at district demonstration farms, and this essential part of agricultural education is yet to be planned. Two important things come to mind regarding its planning: one, of showing the sort of thing that the cultivator can reasonably be expected to do, that is to him economically advantageous and not merely a perfection attainable only by superior resources; and two, of showing simple demonstrations rather than experiments which, with their negative results and inclusion of practices to be avoided, leave a confused impression on the untrained mind. Technical men will not readily support the view that the rural Sudanese have little to learn about plant and animal husbandry within the present limits of their resources. 'What I accuse them of', wrote Gertrude Bell of her beloved Arabs of Syria, 'is not that they choose to live differently from us: for my part I like that; but that they do their own job so very badly.' Whether it be tying baggage on to a camel, nursing a sick animal, or planting a date-palm, the Sudanese cannot in general be acquitted of a similar charge. Failure to apply traditional knowledge, and lack of innate urge to do things well, contribute as much as ignorance to low standards of performance, but tradition is not always right and the gaps in knowledge are many. No traditional belief, however seemingly ridiculous, can be rejected without search for a grain of truth, but few can be wholly accepted without verification.

Dissemination of factual information is one thing; education is another. It is useless to show a man how, by expending more effort, he can double his output, when he is well content with things as they are. He will thank you more for showing him how to achieve his wonted output with less effort. Over large parts of the country increased economic prosperity finds expression in temporary excesses or in an increase of the uneconomic fraction of the live-stock population rather than in any improvement in standard of living. Social approval and an uninstructed conception of security both urge towards cattle ownership and conservatism and away from acceptance of new ideas and new ways of living. This lack of incentive for self-improvement is education's greatest enemy and greatest

justification. The fatalism that was a virtue in times of strife and famine has become a vice in times ripe for progress. Reinforced by the climate, by the harsh nature of the country, and, to an incalculable degree, by low health, this inertia is an obstacle that calls for a more concerted attack than it has yet had to bear. Spasmodic propaganda from agricultural, medical, and political officials has little effect. In the more backward areas schools, if opened, would not be welcomed; in the more enlightened areas schools alone can achieve little, as shown by the large proportion of ex-schoolboys who lose even their literacy. The inertia needs attacking simultaneously in old and young, and at all points of village life.

Women's Education

Reference has been made once or twice in these pages to the beginnings and growth of education for girls. Numerically it compares poorly with boys' education, but there has recently been a substantial increase in British staff, plans for additional intermediate schools are well advanced, and a Government Secondary School for Girls has just begun. Government opinion was made clear in the speeches at the reconstitution of the Gordon Memorial College, which was able to give proof of its intentions by the admission in 1945 of its first woman student. The following estimates of recurrent expenditure in 1945 are self-eloquent:

	£E.
Boys' Elementary Education . .	77,800
Boys' Intermediate Education . .	30,000
Boys' Secondary Education . .	31,000
Boys' Technical Education .	7,000
Total: Boys' Education . .	145,800
Gordon Memorial College . . .	57,000
Girls' Education, all levels. . .	29,000

The supply of facilities for the education of girls lags behind the demand, though not so markedly as with boys' education, and it is difficult to judge the extent and sincerity of the demand from the relatively vigorous outcry ensuing from the small numbers of educated women.

It is regrettable that it is necessary even to-day to have to point out to the educated that modern higher schools, and aspirations to cultural equality with more advanced peoples, are incompatible with the attitude and customs associated with the general run of women in the Moslem Sudan, and to have to argue repeatedly that without education of women and girls the desire for higher standards of life, and the achievement of those standards, will be immeasurably hampered. 'Better wives and mothers' has almost become a slogan, to the exclusion of the idea of the value of educating the female half of the community as people who can bring their contribution of ideas, initiative, and stability to the cause of progress. Elsewhere it is becoming increasingly accepted that woman's place is not only in the home but that her qualities are needed in a wider field. A parliamentary critic recently said that what is needed is not more good women members (interested specifically in women's affairs) but more good members of whom a larger proportion should be women. It is to be hoped that other services will follow the example of the Foreign

Office in taking advantage of the benefits to be gained from the utilization of women in more responsible posts. Until women share the responsibility of directing policy there is danger that male diffidence in administering female affairs may lead to a recession in the position of women in countries like the Sudan where both facilities and tradition favour the progress mainly of men. In the remoter districts the women are sturdy and play an important part in tribal life; education tends to bring seclusion and purdah, at present regarded as symptoms of sophistication. This can be counteracted, over a long period of time, only by educating women to play a part in public life, and by the development of a class of professional women in no way inferior to their male counterparts. The various branches of agriculture have proved acceptable occupations for women in countries less preponderantly agricultural than the Sudan; they are likely to provide one of the chief fields of action for women in this country, and every rural girls' school will need to bear this in mind within the limits of its scope. To sponsor the training, particularly in the early days of the movement, of Sudanese women for the professions, professional European women are needed. When the time comes to develop poultry, dairy, and horticultural research at the School of Agriculture, the recruitment of women to these posts would open the door to these professions for Sudanese girls.

Mention has been made of courses for headmen and headmen's agents at district demonstration farms. Not only should these courses include instruction in public health and other social matters, they should provide married quarters and tuition for wives. No opportunity can justifiably be neglected, and whenever married men are under instruction, whether at Bakht er Ruda, Shambat, or elsewhere, advantage should be taken of the opportunity of educational contact with their wives. Such schemes of adult education and various types of schools for the young will, in the nature of things, increase, but point and direction need to be given to the whole by a comprehensive programme of community education; and here, having digressed to bring women into their proper place in the picture, the narrative picks up the loose end of the previous section.

Community Education

There is need to know far more intimately than is known at present the people whom we are planning to educate. What do they want to do? How can they best do it? What do they need? What are their hopes and fears, their crafts and beliefs? How can we, for example, presume to teach dietetics without intimate knowledge (locally diversified) of local foodstuffs, culinary methods, tastes, and household economies? What is our picture of an improved rural population, and is it practicable in all its details? Community education, then, in the first place, is a task of research.

In 1944 Education Department staff based on Bakht er Ruda made a start on some aspects of this all-important work at Umm Gerr and Fatisa on the White Nile. These are the sites of two large pumping-schemes recently installed to provide alternative livelihood for people whose mode of life had been changed by the filling of the Jebel Aulia Dam reservoir. The population is therefore in process of adapting itself from a

semi-nomadic pastoral existence to a sedentary life with the cultivation of cotton as its economic basis. A supervisory board which includes the district departmental officials controls the experiment and is the means by which the essential co-ordination of departmental effort is obtained. The main executives are the newly appointed Adult Education Officer (part

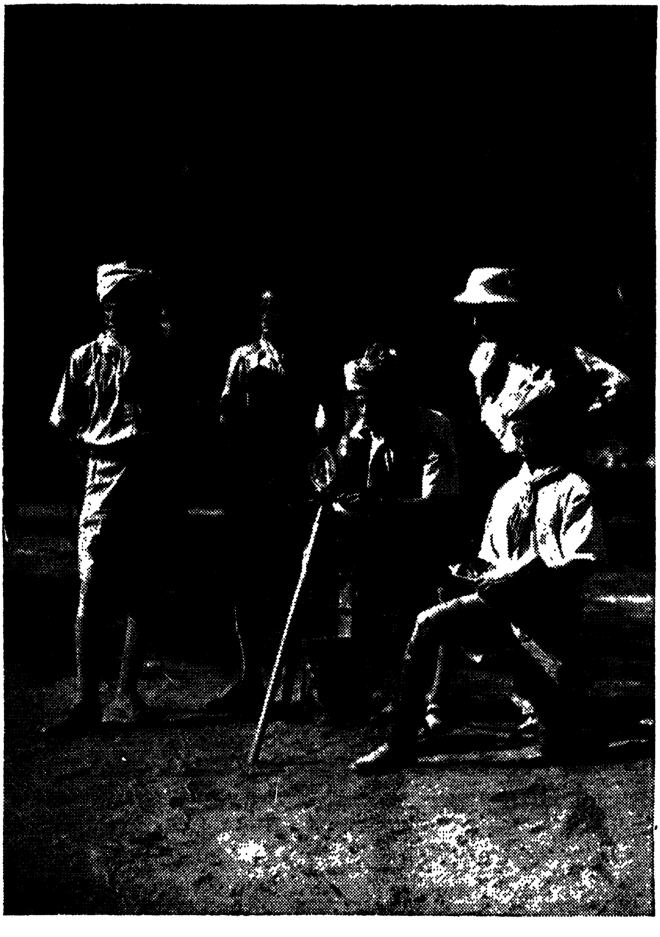

FIG. 75. Boy Scouts and Rover Scouts learning to use a heliograph at Khogalab Camp (*photo V. L. Griffiths*).

time) and his assistant, and specially selected elementary school head-masters have been posted to the two villages and maintain close contact between school and parents. The aims of the modern elementary school may be summarized as good citizenship and better standards of living. The problem of enlisting the sympathy of the parents with these aims, and creating an atmosphere in which the schools can be effective, is tackled by giving short courses in civics to the influential men of the village who constitute the Village Council. Additional courses, up to 3 months in duration, are given to some, in technical subjects such as public health,

agriculture, and veterinary hygiene. The object of these courses is not only to awaken the villagers to new ideas and to acquaint them with what the Government is trying to do for them, but also to break down the attitude that, for example, mosquito control or good irrigation is solely the concern of the local subordinate Government officials and that the villager has no responsibility in such matters. Men receiving these courses are ex-officio members of the Councils and receive a small salary for their work, which is continuous and regular, as propagandists.

The results of this experiment, too early to assess at present, will provide invaluable experience for the time when a full-scale attack can be made on this vital problem of the education of rural communities in the Sudan. In outline it would start somewhat as follows. A team of highly qualified men and women, preferably Sudanese but inevitably mainly British at first, representing agriculture, education, housecraft, health, handicrafts, and animal husbandry would settle down in a selected locality to study in detail every aspect of the lives of the people. They would pass on to considering the needs, and would experiment with means to meet those needs. The institution of co-operative activities would doubtless gain a place, for elsewhere the educative value of co-operation not only in material matters but in teaching the discipline and responsibilities of democracy has been proved, and the economic value, lying in fair prices for produce and protection against the credit merchant and trashy imports, is undisputed. The village school would be reinforced by a village library of books and periodicals of which many would need to be produced by a team (Arabic Publications Bureau) appointed specially for the purpose, for there is sad lack of suitable reading-matter. The habit of reading, raising literacy from a humble tool to a constant stimulus, will increase a hundredfold the return for expenditure on literacy schooling which is at present largely wasted.

Such studies would not give direction only to educational practice, they would give a lead to the work of nearly every Government department. Investigations into the best use of local resources might indicate changes in methods of plant and animal husbandry that would call for restrictive legislation; social and health recommendations might call for measures of compulsion. It is no more proper for a Government to indulge unduly the reluctances of a backward and ignorant people than it is for a parent to indulge a child who shirks his lessons and prefers to lie abed in the mornings. Like other British professionals in the country the community education team would be training Sudanese understudies to replicate their activities elsewhere. They would move on from a village leaving behind new crafts and new needs, and a people stimulated to want them and trained to satisfy them. Initially the process would be very slow—there will be those who will say it would be expensive—but it would be thorough, lasting, and would attack the heart of the matter. Against such a background the products of the various schools, from sub-grade to higher, can become fully effective. By such means the country can peacefully develop its inheritance, and political stability be vested with the productive rural majority, guided to a wider cultural and material life and awakened to the responsibilities of citizenship.

CHAPTER XIV

NUTRITION

NUTRITION IN THE SUDAN[1]

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War as a Stimulus to the Study of Nutrition

AS the first world war came to its weary close, the nations of the world focused their attention not on the pageantry of great military events but on two of the more sombre attendants of war—famine and disease. A virulent pandemic of influenza quickly killed a greater number of people than had 4 years of battle; typhus raged throughout much of Europe; thousands of dysentery and malaria carriers returned to their home areas to serve as potential disseminators of these diseases; Denmark, that had happily sold its animal fats and dairy produce for 4 years while the market was so favourable, faced a heavy incidence of xerophthalmia due to deficiency of the fat-soluble vitamin A; in Austria famine oedema and rickets came into prominence, and in other countries affected by the food shortage the increase in deaths from tuberculosis over the 4 war-years was: 61 per cent. in Germany, 44 per cent. in Italy, 35 per cent. in the Netherlands, and 15 per cent. in Great Britain.[2]

These facts, in conjunction with the prominence in public consciousness of the mutual blockade system, whereby the belligerents each attempted the denying of food essentials to his adversaries, naturally turned attention to nutrition and coincided with important work on the fat-soluble vitamins A and D, in America by McCollum, and in England by Mellanby, so that in the uneasy peace between the two wars it was natural enough that progress was made by scientists of all countries in the study of nutrition. The advances were particularly in our knowledge of the protective elements, the minerals and vitamins, and culminated sociologically in the reports on nutrition of committees of the League of Nations in 1936 and 1937.[3] In these, technical experts representing

[1] This article was originally read as a paper at the Sudan Cultural Centre, Khartoum, on Wednesday, 25 April 1945.

[2] Evang, K. (1944), 'Post-war Nutritional Relief', in Discussion, *Proc. Nut. Soc.* ii. 185.

[3] (*a*) League of Nations (1936), 'The Problem of Nutrition': vol. i, *Interim Report of the Mixed Committee.* (*b*) *Final Report of the Mixed Committee*, Geneva.

some fifty or so nations agreed on certain desirable daily standards of intake of the different food elements for men, women in pregnancy and lactation, growing youths, men doing hard work, and so on. These standards were to enable such persons to enjoy optimal health. This was a truly tremendous advance, although there soon emerged the sobering facts that if all the foods produced in the world were pooled, they could not satisfy these standards for everyone, and that even if they could, existing political, economic, and social barriers could not secure this distribution, there being no administrative machinery for such a procedure. Incidentally these committees drew attention to the interrelationship between health, nutrition, agriculture, economics, and education.

During the second world war this increased knowledge of nutrition enabled armies to be optimally fed and certain nations to be rationed in reasonable compromise with available stocks. Also, unfortunately, it enabled the *Herrenvolk* to select and use their plunder of occupied territories so efficiently that, whereas they themselves were still, even in the final phase, as well fed as Britain, the countries they had plundered were mostly on starvation dietaries; for example,[1] Czechoslovakia in 1942 was estimated to be receiving 1,900 calories per head, while in Poland, Poles received 700 and Jews 400: these rations are almost unbelievable, and they provide a strange practical paradox—that of a lethal diet. The Danish rations have been 1,400 calories, but meat, fish, and potatoes have been unrationed. In Holland in 1942, where rations gave 1,800 calories daily, there was a 43 per cent. increase in the adolescent death-rate and one of 31 per cent. in that of children under 4. Belgium in 1942 was on a ration of 1,000 calories; in France rationing gave the average person 1,000, heavy workers received 1,320, and very heavy workers 1,450, the optimal standards being 3,000, 4,000, and 4,500. In Greece—it is thought—the average calorie intake was down to 900, and, as is well known, deaths from starvation were wholesale.

Nutrition in the Post-war World

The problem of feeding the post-war world and establishing universal right feeding is gigantic and has two aspects, the national and international. Nations in this practical world must secure a reasonable ration for their own people first, but humanitarianism has demanded the feeding of the distressed countries, and there is a growing feeling that a well-fed world will be more contented than has been a world in which, while some nations were well fed, others existed alongside, or in association with them, with large masses of their people on diets far below those compatible with good health. As a natural consequence, there was held at Hot Springs, Virginia, in North America in 1943 the United Nations Conference on Food and Agriculture, attended by the delegates and technical experts of forty-four nations representing 75 per cent. of the

[1] Bourne, G. (1944), 'Post-war Nutritional Relief', in Discussion, *Proc. Nut. Soc.* ii. 189.

world's population. They made some historic statements and recommendations,[1] for example:

'Whereas

1. Malnutrition is responsible for widespread impairment of human efficiency and for an enormous amount of ill health and disease, reduces the resistance of the body to tuberculosis, and enhances the general incidence and severity of familiar diseases;
2. Mortality rates in infants, children, and mothers are higher in ill-fed than in well-fed populations;
3. Food consumption at a level merely sufficient to prevent malnutrition is not enough to promote health and well-being;

The United Nations Conference on Food and Agriculture

Recommends:

That the several governments and authorities here represented undertake immediately:—

(*a*) To ascertain the prevalence of specific deficiency diseases among their respective peoples,

(*b*) To deal with them by suitable dietary and therapeutic measures,

(*c*) To take appropriate steps to prevent their recurrence.'

The feeding of peoples in a gross sense, that of keeping them alive, has, of course, always been a matter of practical importance: the grain issue to the population of Imperial Rome was a perennial topic, and famine relief in countries like India and China—and in the Sudan also—has from time to time required the intervention of governments, but feeding in the more refined sense, that of the provision of a balanced diet or a reasonable approach to it, has now become a project of the first political and sociological importance, nationally and internationally.

Improper Use of Foods available

In the present stage of human development nutrition is inseparably associated with agriculture, animal husbandry, fisheries, and the manufacture of sophisticated foods, such as those that are preserved, tinned, and bottled. It is useful to remember that while all of the world's population consume food, no fewer than 70 per cent. are engaged in its production, and a relatively small proportion of this 70 per cent. produce enough food to give, even themselves, ideal diets. Above has been mentioned that Denmark suffered severely from vitamin A deficiency because she sold the fats containing it, preferring money to health. Similarly, I believe it is a fact that before this last war the best rice in the world was produced in Java but was not eaten there; it was exported because of the price it commanded, and an inferior rice was imported as the nation's staple.

Recently I visited a Gamu'ia nomad encampment in the Umm Inderaba Wells area some 70 miles west of Omdurman and found quite by chance, in the course of a few hours' contact, a case of night blindness and another of degeneration of the surface membrane of the eye, both due to vitamin A deficiency. It was the local practice to use only skimmed milk; the milk fats they made into clarified butter ('samn') which they took for sale by camel-back a journey of 70 miles to Omdurman. Similarly, one of

[1] *Final Act of the United Nations Conference on Food and Agriculture* 1943, 20 (London, H.M.S.O.).

the few sources of vitamin C available to them was an annual crop of wild 'nabaq' berries (*Ziziphus spina-christi* Lam.) occurring in a nearby wadi, but again, few if any were eaten; they preferred to take them the long weary journey by camel for sale in Omdurman. Occupied Europe is now starving, but it has been estimated that even before the war between one-third and one-quarter of the population was undernourished. Assessments of the food situation in India have shown that the large majority of the 400 millions of its people do not get enough to allay hunger,[1] and in England herself it was estimated before the war that 50 per cent. of the population had below the optimum intake of vitamin A. These points should be remembered if nutrition and malnutrition in the Sudan are to be kept in perspective.

The Nature of Nutrition

The nature of nutrition will now be discussed mainly in relation to the Sudan but with considerable illustration from elsewhere, for the number of significant measured observations on nutritional phenomena in the Sudan is negligible. Interest in nutrition may be centred on any of several aspects: there is the economic, the relationship of income to food production, distribution, and purchase; the anthropological, the relationship of the food pattern to the cultural and social pattern; there is the interest of the gourmet in the cooking, aesthetic, and palatal aspects, but behind them all is an aspect of ultimate primary importance—the relationship of feeding to physical and mental welfare, that is, the degree to which malnutrition is present.

Taking as our standard individual a well-fed man of average height, doing an average day's moderately hard work (say a car driver), in a temperate climate, it is considered by most authorities that the daily food need is 3,000 calories, the calorie being the unit of heat-energy used in the quantitative assessment of the energy value of a diet or food substance. During hot weather less is required, and women and children require less because of their smaller body-weight. In cold weather more is required, because the body has to produce extra heat to maintain itself at its constant temperature level; wind and sunshine increase the need, the latter half of pregnancy and the function of suckling increase the need also, for here an extra individual has to be fed. Adolescents, particularly the active boy, have a higher need than any other group excepting that of adult men doing very severe work in cold weather, such as lumbermen or dock labourers, whose need may be as high as 4,500 calories. In the world's best standard, adolescent boys are listed as requiring 3,800 calories daily.

In addition to there being a standard for the gross amount of food in its energy aspect, food must be balanced in its elements. There are the food substances like egg-white and meat tissue, the proteins, a minimal intake of which is necessary if a certain type of waterlogging of the body called famine oedema is to be avoided and if the disease called pellagra is not to occur. There are the fats, the optimal amount of which for a

[1] Evang, K. (1944), 'The Hot Springs Conference', *Proc. Nut. Soc.* ii. 165.

diet is unknown. However, there are important functions known for it: it gives twice as much energy weight for weight as do other food elements, and animal fats are important vehicles of the vitamins A and D. Carbohydrates, of the chemical nature of starch and sugar, supply in most parts of the world the greater part of mankind's food.

Proteins are necessary for the repair of broken-down tissue and for growth, and fats and carbohydrates are primarily sources of energy, but there are two other groups of very important foods called the protective foods, the minerals such as iron and calcium, and the vitamins A, B1, B2, C, D, &c., most of which have by now received names instead of letters. Deficiencies of these protective foods cause disease; that of iron, anaemia; of calcium, bad teeth and the bony deformities known as rickets; of vitamin A, night blindness, dry skin, and susceptibility to certain infections; of B1, the disease called beri-beri, the affection of those on monotonous rice diets; of B2, in conjunction with protein deficiency, the disease pellagra, the affection of those on monotonous maize diets; and of C, scurvy, the affection of those on diets deficient in fruits, vegetables, and fresh meat and pre-eminently the deficiency disease of sailors and prisoners, closed communities with no opportunities of supplementing their diets as they feel inclined. For all these protective food elements optimal standards have been established and accepted by most experts, but there is less agreement on the minimal values below which frank deficiency disease may be expected. It has been said that roughly a fifth of the optimum quantities in minerals and vitamins will support health short of frank deficiency disease, but it would be a bold man—or an ignorant one—who would advocate such quantities as appropriate for any diet.

There are obviously different levels of physical efficiency between these optimal and minimal values, and a person very near the minimal level is apt to be precipitated into frank deficiency disease if his energy need is increased, for whereas, previously when his energy level was, say, at 2,400 calories his vitamin C intake was just sufficient to keep him free from frank scurvy, yet increase his calorie need to, say, 3,600 by exposure to cold and a heavy increase of work and he now requires a 50 per cent. *pro rata* increase in his vitamin C, for his body is living half as fast again: unless he receives this increase he develops the active disease. This has been illustrated many times by scurvy appearing first amongst the hardest-worked members of the community in polar expeditions, sieges of towns, and sailors and soldiers at sea.

A good illustration occurred in east Prussia during the 1914–18 war in a German P.o.W. camp where there were comparable communities of Russian and Rumanian prisoners on similar ration scales.[1] One morning, figuratively speaking, the Germans awoke to find the Russians afflicted with scurvy and the Rumanians with pellagra. Russia has scurvy as its classical deficiency disease and Rumania, a maize-eating country, is subject to endemic pellagra.

The bodies of Russians were particularly deficient in stores of vitamin

[1] Bigwood, E. J. (1939), *Guiding Principles for Studies on the Nutrition of Populations*, 153 (Geneva: League of Nations).

C and the Rumanians were already pellagrous or pre-pellagrous and pellagra has, as one of its characteristics, the recurrence of active disease in response to such stimuli as cold, bright sunshine, or hard work, i.e. to factors increasing the energy need of the body. I have no doubt that this remarkable outbreak was precipitated by the advent of the bright sunshine of spring, possibly associated with increased work or withdrawal of winter clothes.

Similarly in the Sudan in the winter of 1941–2, in P.o.W. camps holding African prisoners and with outbreaks of mixed scurvy (cf. fig. 77) and pellagra, it was noted with interest that there was a severer incidence among the camps in which the inmates were more exposed to sun, wind, and cold by being accommodated in grass shelters with head cover but without sides than there was on those housed in tents or grass shelters with the usual grass sides as well as roofs. Thus the existence of dangerous deficiency states short of frank classical disease is an established phenomenon.

On the whole, the energy foods, like grain, roots, and vegetable oils, are comparatively cheap while the foods rich in protective elements such as meat, milk, butter, eggs, and fruits, tend to be more expensive. Naturally enough, the food pattern of a community is decided by environment, climate, and cultural state. The Zande of Equatoria live largely on grain and other vegetable items; they have little meat and no dairy products, as tsetse fly prevents the local existence of cattle. The nomads of the Sudan, if rich in animals, have ample milk, butter, and meat for most of the year, and, together with good body reserves, probably the nutritionally rich food millet beer ('marisa'), to help them over the dry season of dearth when the milk-supply may drop to a negligible quantity. Very much worse off are nomad communities who have fewer animals or who sell their milk fat as clarified butter ('samn') or who do not find themselves able to accept millet beer in its most useful light, as not primarily an alcoholic drink, but first and foremost a vehicle for good protein, iron, calcium, and the vitamins A, B, and C. The Nilotics have their fish, their cattle, their wholemeal grain, and their millet beer. Settled communities on the river may have cattle, fruit, and vegetables in addition to grain. Wealthy town-dwellers in Khartoum, as in Cairo and London, have, in normal times, all they may wish either fresh, dried, preserved, canned, or bottled. But in all communities there is to be found malnutrition; it goes hand in hand with poverty, lack of knowledge, and food faddism, and in almost any community in any part of the world there will be found those who cannot afford, and therefore have no access to, the more expensive foods available to their more fortunate fellows, foods which almost invariably are those containing the protective elements.

At the same time many communities have evolved naturally, in response to their environment, dietaries which are found to give the best local balance available. An unusual type of illustration of this occurred in the southern Fung in 1939, where there was under observation a community at Ulu who suffered three seasons of locust visitation. They had millet as their staple, some 2 lb. a day, complemented by meat which they obtained from local nomad Arabs with whom they bartered surplus

grain; in addition they brewed millet beer, thus obtaining a useful supply of the vitamins of the B complex and vitamin C. Their diet appeared on a rough assessment to be some 3,300 calories daily. They showed signs of chronic deficiencies of vitamin A and the riboflavin part of the B2 complex only. In the third season they appeared to have really got into nutritional difficulties; their granaries were empty, they were able no

FIG. 76. Deficiency of calcium or phosphorus or vitamin D or ultra-violet irradiation. The condition of rickets (*courtesy of S.M.S. Graphic Museum*).

longer to borrow from kindred communities, and there was no cash crop available apart from a negligible quantity of gum. The men, however, hunted the district clean of guinea-fowl which they dried in the sun and then stored for consumption over a period, while the women and children dug up large quantities of a wild yam, the cluster yam (*Dioscorea dumetorum* Pax.), which they freed from its poisonous alkaloid dioscorine by pounding and washing. In addition they collected and ate the 'lalob', the fruit of the 'heglīg' tree (*Balanites aegptiaca* Del.), and also 'dōm' nuts, the fruit of the 'dōm' palm (*Hyphaene thebaica* Mart.). After five months of this diet they showed no signs of deficiency of protein, no increased signs of vitamin A deficiency, no signs of pellagra, and no signs of scurvy. There were, however, hunger, indigestion, and increased protuberance of

the children's bellies, probably a mild degree of B1 deficiency. Their calorie intake was roughly assessed at 1,100 calories. The onset of the rain and Government relief at this point put an end to what may have been an imminent catastrophe.

The episode suggests that communities may adapt themselves in some degree to a non-optimal diet, though these bush products are very far

FIG. 77. Deficiency of ascorbic acid (vitamin C) in a Sudanese. The condition of scurvy (*courtesy of S.M.S. Graphic Museum*).

from being deficient in protective elements. We know this adaptation can be made to some extent for protein, vitamin C, and salt, but survival at such a level does not necessarily mean efficient living. The story of the outbreak of scurvy and pellagra amongst the prisoners of war in east Prussia is a sufficient warning of this.

Malnutrition to be sought in Vulnerable Groups

If there is malnutrition in a community, it may best be sought in what are called the vulnerable groups, those with the biggest calorie need, and these are, it may be remembered, pregnant and suckling mothers, school-children, particularly adolescent boys, and men engaged in hard outdoor work.

Non-optimal nutrition or malnutrition has several aspects. Firstly,

there is crude famine, an inadequate number of calories, such as has been illustrated in the comments on the food intakes in Occupied Europe. It is shown by growth short of the normal in the immature—those still growing—and by loss of weight in the adult. In the Sudan we have a difficulty right away here because we have no normal standards, Sudanese being mixed in racial elements, and the influence of heredity being not assessable. What figures we have suggest the existence of sub-optimal

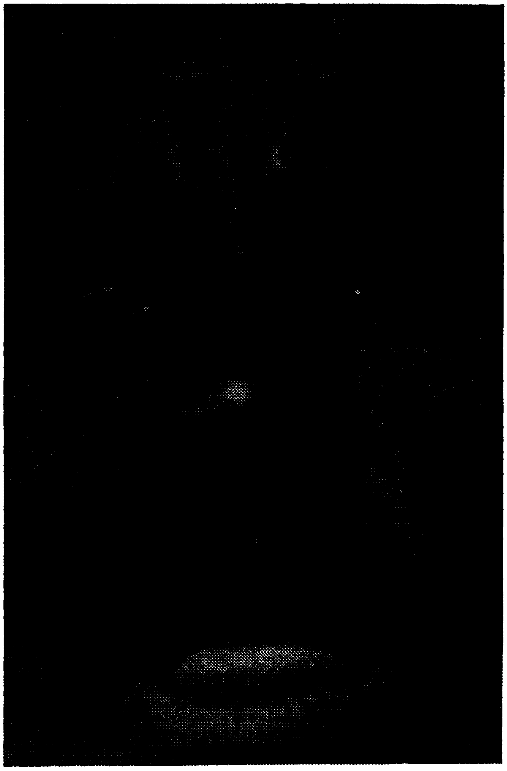

FIG. 78. Deficiency of riboflavin (part of vitamin B2) in a Sudanese. The condition of ariboflavinosis (*courtesy of S.M.S. Graphic Museum*).

growth, and it is an everyday occurrence to encounter children much below the height and weight of fellows of the same age. Secondly, there is the occurrence of frank deficiency diseases due to lack of specific minerals and vitamins, such diseases as rickets (fig. 76) due to lack of calcium or vitamin D (which may be made by sunlight on the exposed skin), scurvy due to lack of vitamin C, beri-beri and pellagra due to lack of the B complex, and eye and skin affections due to a deficiency of vitamin A.

Malnutrition in the Sudan

For examples of most of these we have not far to look, if the looking is done properly. To speak of the Khartoum area only, the residues of rickets may be seen in any busy street in Khartoum in the commonest

form, that of deformed legs; the degree of incidence, however, is certainly less than was formerly the case in England. Scurvy (Fig. 77) has been seen in the last 5 months in Khartoum, in prisoners, lunatics, adult scholars, schoolboys, schoolgirls, and nondescript persons; not a great deal perhaps, but it has been noted. Pellagra (Fig. 79) is more difficult to be definite about in a satisfactory way, as the exact nature of the condition is still not quite clear, but what is quite clear is that deficiencies of good protein

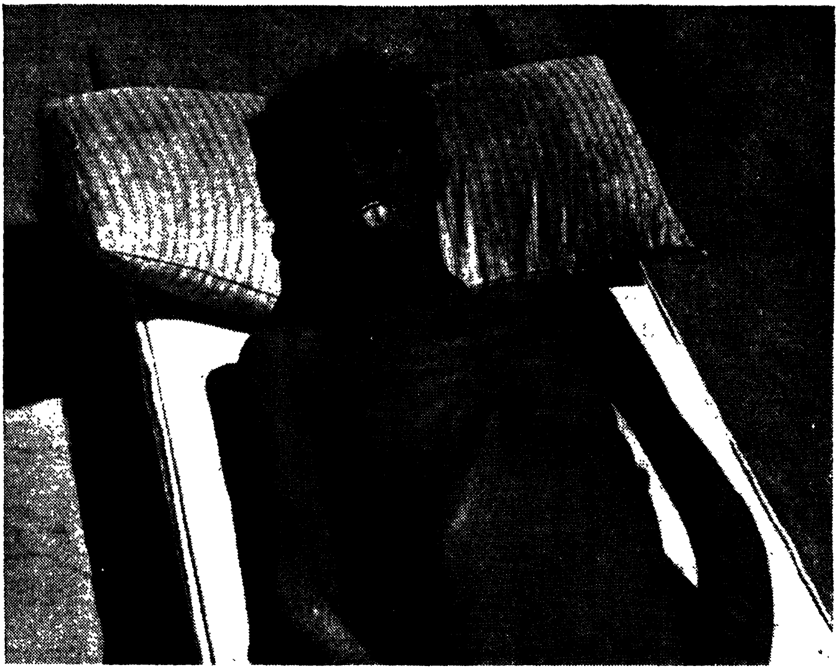

FIG. 79. Pellagra in an Abyssinian in the Sudan. Developed on a meagre diet of millet with lack of adequate protective foods (*photo Corkill*).

and of nicotinic acid and riboflavin—two parts of the B2 complex—contribute to its cause, and that in its nature, when endemic, it recurs twice yearly, at the cold peak and at the hot peak, and is characterized by certain signs, for example, wasting, a cracked paving-stones appearance of the exposed skin, and a diffuse powdering of the face with smaller or larger yellow excrescences at the mouths of glands in the skin; severer cases may develop dysentery, sore mouths, mental disorder, and a heavy black skin eruption. This condition in a latent or *fruste* form is widespread amongst the poor and may be seen in a more developed, but still apparently comparatively mild form, amongst the poorer Batahin of Abu Deleig,[1] particularly that portion of the community which will not touch millet beer.

Vitamin A deficiency, evidenced by dry skin, a nodular skin of a certain

[1] Corkill, N. L. (1934), 'Pellagra in Sudanese Millet Eaters', *Lancet*, 30 June 1887.

type called toad-skin, night-blindness, and degeneration of the surface membrane of the eye, is quite frequently encountered, and as an illustration to deal with recent findings only, this degeneration has been seen in the Khartoum area recently in two prisoners, a lunatic, a schoolboy, and a nomad. The other signs can be found at any time with ease if looked for in the local population, and night-blindness due to deficiency

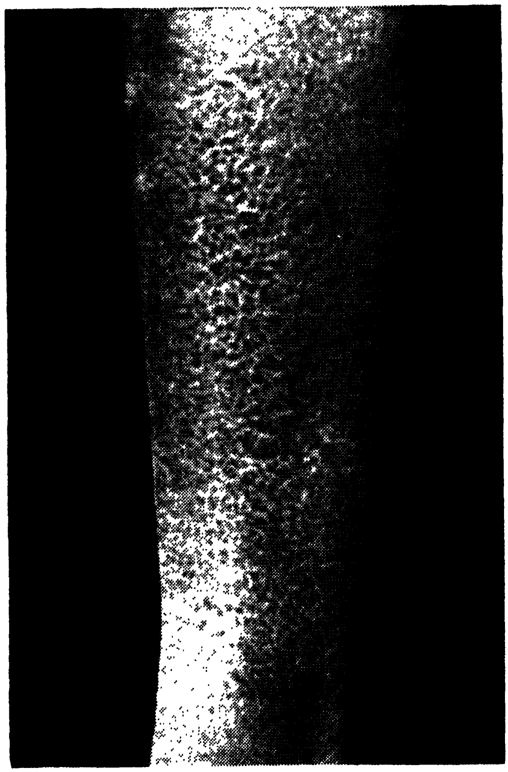

FIG. 80. Deficiency of nicotinic acid (part of vitamin B2) in a Sudanese. Mosaic skin on a leg. Encountered most commonly in cold weather. Fairly common in lepers and in the senile (*courtesy of S.M.S. Graphic Museum*).

of vitamin A is well known in the northern and central Sudan as is witnessed by the innumerable folk-names for it, and the popular and correct beliefs that it is due to a lack of fresh meat and vegetables and is cured by eating liver: liver is rich in vitamin A.

An increase in the incidence of tuberculosis has been shown above to have been associated with a decrease in the quantity and quality of food —particularly the vitamin A containing fats. In the Sudan it is fashionable to say that the disease is on the increase. That this is true or otherwise is difficult to establish as so many factors, statistical, sociological, and diagnostic, are involved, but it seems an acceptable proposition that Sudanese, like most Africans, are very susceptible to tuberculosis and

other respiratory diseases, and that on the whole their diets, like those of most Africans, are deficient in animal fats and vitamin A.

Another aspect of malnutrition is that in better-fed communities the rates for maternal mortality, abortion, still-birth, premature birth, and for neo-natal and infantile mortality are less than those in worse-fed communities. Acceptable statistics have shown this, but the deduction that it is the better food that is responsible cannot stand unqualified, for better feeding nearly always goes with better economic status, which

FIG. 81. Diet of settled Arabs. Ga'aliin tribe at Shambata in the Fung. Right to left: sheep and goats as meat, *Sorghum* millet (dura), dried *Hibiscus esculentus* ('weika'), sesame seed ('simsim'), dura porridge ('lugma'), gourd of fresh milk ('laban'), pot ('kantush') of millet beer ('marisa'), *Capsicum* pepper ('shatta'), salt ('melh'), and bulb onions ('basal') (*photo Corkill*).

will usually mean a higher level of hygiene, of domestic living, and availability of skilled nursing and medical attention. None the less it is indisputable that a mother with the right food intake in calories and with optimal protein, minerals, and vitamins will stand a better chance of arriving safely at term, passing safely through labour, and producing a healthy, robust child. In Toronto,[1] in or about 1941, an experiment in supplementing the diets of pregnant women showed easier pregnancies and labour, improved health in the puerperium, and decreased morbidity and mortality at birth. A London experiment[2] in 1942, conducted by the People's League of Health, showed that better feeding gave protection against toxaemia and a decrease in premature births. In Glasgow[3] in 1941 were assessed the diets of 300 mothers, 100 who had produced stillbirths, 100 who had produced premature babies, and 100 who had produced full-term babies. The intakes of calories, protein—particularly

[1] Huggett, A. St. G. (1944), 'Diet in Pregnancy', *Proc. Nut. Soc.* ii. 23.
[2] Ibid.
[3] Graham, S. G. (1944), 'Nutritional Defects in Infancy', *Proc. Nut. Soc.* ii. 67.

animal protein—calcium, and iron were successively greater in these respective groups.

In Omdurman last year (1944) the rates per 1,000 contrasted with those for England in 1938 were: maternal morbidity 3·1 to 2·97, and infantile mortality 95 to 53. These Omdurman figures are really very good for a native town in the tropics. A first-class antenatal and child-welfare centre service is in being in Omdurman, and so it seems fair to

FIG. 82. Diet of nomad Arabs. Nefedia tribe in the Fung. Right to left: vessel ('batha') containing clarified butter ('samn'), *Sorghum* millet (dura), a porridge from it ('asida' or 'lugma'), soured milk ('rob'), cow-peas ('lubia hilu'), and dried *Hibiscus esculentus* ('weika'). Millet beer is rarely made or drunk by this tribe (*photo Corkill*).

say that better diet—that is a more balanced diet—may reasonably be expected to produce even better rates.

Lastly, a good nutritional status in a patient, and his good feeding when ill, are known to result in shortened convalescence and quicker healing of fractures and the wounds of surgical cases, and it would be reasonable to expect a lesser incidence of complications and cross-infections on a diet well supplied with calories, proteins, and protective elements. However, we have at present no figures to support this contention.

Tribal Diets in the Sudan

Much that has been said has related to Khartoum, but when I think of malnutrition in the Sudan I think primarily of the poorer and more remote tribal communities with few or no animals, and possibly relying mainly on their cereal crop, with no pulses and roots to save the situation if the rains fail and the young grain is parched away, or if locusts arrive. Again, the plight of nomads who are poor in animals is serious, for in the dry season the available milk has become negligible.

Diet scales for troops, schools, prisons, and hospitals reflect the nature of the natural Sudan diets in general, though some of them may be better in some ways than some natural diets, but practically all Sudan diets, natural or devised scales, have the same characteristics, which are relative shortages in animal protein, calcium, salt, vitamin A, riboflavin, and vitamin C. Thanks to the excellence of wholemeal millet as a staple cereal, in its content of iron and B1 the anti-beri-beri vitamin, anaemia

FIG. 83. Diet of immigrant stock. Fellata from West Africa at Maerno in the Fung. Right to left: sheep as meat, grain pounded in characteristic mortar, *Pennisetum* millet ('dukhn'), *Sorghum* millet (dura). Front row right to left: pea-nuts, dried fish, dura cake ('wena'), balls of crushed sesame ('dikwa'), balls of 'dukhn' cake ('gadu gadu'), cow-peas, *Hibiscus sabdariffa* leaves ('karkadē') for relish, dried dates, jujube confection ('tabūl'), dried jujube berries ('nabaq'), dried *Hibiscus esculentus*, and soured milk. No millet beer is made or drunk (*photo Corkill*).

from nutritional causes and beri-beri need not be feared, and in communities that use peanuts adequately as a food, pellagra will be unknown, for its values in nicotinic acid and riboflavin are high.

Balanced Diets important

An adequate diet in the sense of one that will allay hunger is a matter of satisfying the appetite, but a health-maintaining balanced diet is one composed of all food elements, including the protective foods. Maize is nutritionally evil, in that its grows easily, gives a big yield, satisfies the palate and the sense of repletion, but yet at the same time because it is, to some extent, lacking in good amino-acids—important constituents of protein—constitutes a danger to health, and it is a noteworthy fact that all major areas of severe endemic pellagra are those in which maize is,

or was, the staple food; these areas are, or have been, Italy, the southern states of the U.S.A., Rumania, Transcaucasia, Egypt, and France until she reintroduced wheat as a staple. Maize has its modified merits in that in places like the Nuba Mountains it is grown as a quick-maturing 'rains' crop to stave off hunger until the slower-maturing millets and pulses have come to maturity, but its institution as a staple in the Sudan would be inviting disaster, for there is already a natural deficiency of certain of its nutritional complements, animal protein, and riboflavin (cf. p. 273). A balanced diet means the eating daily of meat, fish, eggs, milk, or cheese, butter, fresh or clarified, or a vegetable oil of some sort, at least a pound of a wholemeal millet or bread, some peanuts, some beans, peas, lentils or nuts, some fruit. Those that cannot obtain oranges or mangoes can perhaps obtain 'lalob' fruits (*Balanites aegyptiaca* Del.) or 'nabaq' berries (*Ziziphus spina-christi* Lam.) or 'gangoleis', the fruit of the 'tebeldi' tree (*Adansonia digitata* Linn.), some root vegetable, some fruit vegetable, some leaf vegetable. Those that cannot procure 'melūkhīya' from the market (*Corchorus olitorius* Linn.) can perhaps procure it from the bush or 'tebeldi' leaves—and some salt. These are the things that matter; tea, coffee, and sugar are luxuries.

Improvement of Sudan Diets

Malnutrition in the Sudan calls for action on the following lines:

(*a*) The dissemination of information as to what is a balanced diet so that the best use may be made of what is available in any locality. When cultivated products are unavailable, bush products may be used, a practice actually followed naturally by many of the less sophisticated people.

(*b*) The increased growing everywhere, by every individual who can do so, of vegetables and fruits. These are productive of calcium, iron, and the vitamins A, B2, and C.

(*c*) The cultivation of a palate for fish by a larger public, and a public demand for the exploitation of the marine and river fish foods of the country.

(*d*) The canning, drying, and marketing of meat.

(*e*) The wider cultivation, and greater use, of peanuts and sesame seed, which are excellent protective foods.

(*f*) The adoption of multiple food crops by every community that can do so, not only as ensurance against locusts and drought, but to produce a more balanced diet. Every community if possible should have its cereal, its pulse, its root vegetable, its fruit vegetable, its leaf vegetable, its vegetable oil, and its fruit.

(*g*) A forceful public interest and demand to ensure that these measures receive attention.

For certain small remote impoverished communities in barren localities the future offers little, unless they are translated to other potentially fertile localities.

A NOTE ON NUTRITION IN EQUATORIA PROVINCE

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VERY little is known of what the people in Equatoria Province actually eat since dietary surveys have not yet been made and very few of their staple foodstuffs have been analysed; again, except for some young men medically examined for fitness for military service and the few children attending school, no assessment has yet been made of the state of nutrition of representative groups of the population.

The province may be very roughly divided into four areas:

(1) A northern belt.
(2) A middle zone.
(3) An area in the south-west and west of the province lying along the northern slopes of the Nile–Congo divide.
(4) An area in the south-east corner of the province.

Although these areas merge one into another yet each has, generally speaking, its own particular characteristic climate and soil which determine largely the foodstuffs available to its inhabitants (cf. rainfall map, p. 69).

The northern belt, with an average annual rainfall of about 900 mm., is flat and there is much cracking clay soil; here water lies during the rains and then much of the area is swampy, but at other times there may be a scarcity of water. Here the Dinkas live.

The middle zone, with an annual rainfall of about 1,150 mm., is undulating with some well marked hill systems. The rainfall tends to be higher than in the Dinka area and the country is more thickly wooded. A number of different tribes live in this part, though many of them are more or less closely related to one another.

The third area in the south-west, with an annual rainfall of about 1,400 mm., is more closely covered with forest and is intersected by many water-courses. Its inhabitants are the Azande and allied tribes.

Lastly there is a fourth and smaller area, differing somewhat from the other three; it lies to the south-east, in the angle formed by the boundaries of the Sudan with Abyssinia and Kenya, and has an annual rainfall of about 800 mm. Here the soil tends to be sandy, and conditions approximate those of the semi-desert during some months of the year. The Toposa are the main tribe living in this part.

The Northern or Dinka Zone

The Dinkas, who roam over the northern plains, are pre-eminently a pastoral people—they own large herds of cattle and flocks of sheep and goats. There are probably some 600,000 Dinkas living in Equatoria, and they have about half a million head of cattle and about the same number of sheep and goats.

They cultivate rather more in some places than in others. The main cereal crop is millet (*Sorghum*); they also plant sesame (*Sesamum*), various beans and pumpkins. Milk plays an important part in the diet of the

Dinkas, and although it varies in quantity according to the season of the year, yet it would probably be right to say that nearly half of the Dinkas' food is provided by their animals. Blood is sometimes mixed with the milk.

As the Dinkas range over an area about 500 miles long, there are local variations in their diet; those living in the swamps along the Nile eat a good deal of fish and hippopotamus flesh, those living in the Rumbek area cultivate a fair quantity of millet, whilst the Dinka of the north-west seem to depend less on millet and to eat but little fish.

From about the beginning of January until the end of March, this being the height of the dry season, the Dinkas usually move out of their villages into the cattle camps in the 'toich' lands, living in small temporary huts or in the open. During this time they feed largely on milk, perhaps with some added blood, and a little grain from the last harvest. The girls and women are busy making clarified butter for use in the coming rainy season, whilst the young men often go hunting—their kills are mostly hartebeest, antelope, waterbuck, buffaloes, and sometimes even elephants; much of this meat is dried and kept for later use.

With the onset of the rains in April the people commonly return to their villages and are then busily engaged in cultivating until about the end of June. The fishing-season is in April and May, and a good deal of the fish taken is dried and stored for use in the cultivating season, when clarified butter, grain, and dried meat are also consumed.

At the end of June some of the young men may take a few cows with them and spend the next three months in cattle camps on high ground away from their villages; during this time they live almost entirely on milk and grow fat. They usually return to the village about the end of September to help in the work of the harvest.

The various kinds of millet ripen at different times, but the main crop is harvested in October. Ground-nuts (*Arachis hypogaea* Linn.) are lifted from late June to September and have usually all been eaten by the end of the year. Sesame is commonly harvested in September.

Dinkas also cultivate beans (*Vigna*) and, during the rains, they eat various green salads and pumpkins, which are a favourite both for their fruit and leaves. Although these tribes keep domestic fowls, they do not eat either the birds or their eggs; Dinkas do, however, sometimes eat guinea-fowl and also ducks.

Among other articles of food are: shea or 'lulu' nut (*Butyrospermum parkii* var. *niloticum* Pierre.), which is eaten as a nut and also from which the oil is extracted, fruit of the 'heglīg' (*Balanites aegyptiaca* Del.) and of the 'dolēb' (*Borassus aethiopum* Mart.), the seeds and roots of the water-lily (*Nymphaea lotus* Linn.), fruit of the 'aradēb' (*Tamarindus indica* Linn.) from which a beverage is made, sweet potatoes, the leaves and roots of cassava (*Manihot utilissima* Pohl.), honey, maize, and lady's fingers (*Hibiscus esculentus* Linn.), the fruit of which is eaten both fresh and dried, and termites.

The millet is consumed as a thick gruel ('madidah') and as a porridge ('asīda'), whilst much of it is brewed into native beer ('marīsa') and drunk during October, November, and December.

The 'marīsa' is made by allowing a paste of millet flour to ferment about 3 days with some of the sprouted whole grain; it probably contains a good deal of the vitamin B complex and also some vitamin C.

There are many food 'taboos' among the Dinkas, and they usually concern totem animals or plants; thus a Dinka may not eat of his totem animal, husbands and wives do not eat the flesh of each other's totem animals, and further the prohibition may extend to the totem animals of various blood relatives.

The Dinkas build themselves the usual small circular huts, but they may spend a good deal of the dry season in the open. They wear few clothes; the men are commonly naked as are the children and some of the young women; at times they smear their bodies with ashes, chiefly as a protection against biting-insects.

Their drinking-water comes from pools, water-courses, and a few wells.

They are a tall, slim, active people; the average height of the men is about 1·78 metres. Their bones are well formed, their teeth usually sound, and their skin healthy. Night-blindness—possibly as an expression of vitamin A deficiency—occurs occasionally, but frank cases of scurvy, beri-beri, or pellagra are not recorded. Chronic tropical ulcers are by no means uncommon, and an underlying vitamin deficiency may be a contributory factor in their causation and in their chronicity. An interesting fact is that Dinkas suffer severely when infested with hookworms which, as their diet consists largely of milk, may be associated with a shortage of iron. On the other hand, these people tolerate bismuth well in the treatment of yaws.

At times severe epidemics of cerebrospinal meningitis sweep through the Dinkas, and it has been suggested that a vitamin deficiency may be a contributory factor in facilitating the spread of this disease.

Some of the Dinkas are certainly tall and slim, a few are even thin. Occasional cases of knock-knees and flat feet occur among them, and, if these be due to rickets, then other obvious signs of this disease are rare. Affections of the conjunctiva are not uncommon among the Dinkas, but smoke fires, used to ward off biting insects, are a possible predisposing cause.

Angular stomatitis and 'butterfly' patches on the cheeks and nose are sometimes seen; they may well be an expression of some degree of vitamin deficiency.

Dinkas usually only eat one meal a day and, on the whole, seem to enjoy a fairly good, mixed diet, which is relatively rich in animal protein and fat although it could be considered somewhat short in carbohydrates and vegetables.

These people are seldom short of food but, when they are, the women and children seem to suffer more severely than the men.

On this diet they attain a tall stature, show little evidence of deficiency disease, and are able to live an active physical life. The Dinka is 'independent' in his outlook and, when persuaded to go to school as a boy, he proves himself as intelligent as any of the tribes of the southern Sudan.

The Middle Zone

The people living in the middle zone include such tribes as Latuka, Bari, Nyambra, Mondari, Moru, Kuku, Kakwa, Kaliko, Mondu, and, out towards the west, the Bongo, Balanda, Banda, and Kreish. Collectively these people may be considered to represent the transitional stage from pastoral to agricultural society; the Bari, as an example, seem within quite recent times to have owned many more cattle than they now do, and possibly the same might be said of the Mondu and Kuku.

The Bari, who live around Juba, cultivate various kinds of dura millet, one being of a rich red colour, and also dukhn (bulrush millet, *Pennisetum typhoideum* (Burm.) Stapf and Hubbard; wherever the soil is suitable they plant ground-nuts, and these form an important part of their crops. They also cultivate sweet potatoes (*Ipomoea batatas* Lam.), sesame, cassava, lentils, various beans, lady's fingers, and Jew's mallow (*Corchorus*). During the rains they also gather wild plants, including purslane (*Portulaca*). As in other parts of Equatoria Province, grain is stored in 'gugu'—cylindrical bins about 4 ft. or so in diameter and set on wooden posts at a height of some 3 ft. from the ground.

The millet is commonly ground into a fine flour and eaten cooked as a thick gruel and as a porridge. A good deal of millet is used for the making of beer.

Cassava leaves are bruised and then cooked in the sauces and soups. These leaves contain much vitamin C. Flour is prepared from the cassava roots, but it does not form a large part of the Bari's food. Sesame oil and shea-nut oil are used to a considerable extent.

The Baris own a fair number of cattle, particularly in some places as at Belinian, and they also keep sheep and goats (e.g. in the Bongo area). Milk is drunk whenever it is available, but domestic animals are seldom slaughtered for meat. The Baris are active hunters and eat all kinds of game, snare guinea-fowl and, along the Nile, also catch fish; fish, however, does not seem to form a large or popular part of their diet. They keep domestic fowls in their villages.

The Baris appear to enjoy a relatively good mixed diet: the cereals are of several kinds; the vegetable fats are in fair quantity, as are the vegetable proteins; the animal fats and proteins are obtained mostly from game, fish, domestic animals, and milk; fresh vegetables are available during the 5 or 6 months of the rainy season, whilst native beer provides a source of the vitamins B and C.

The people themselves are active and well developed, the men reaching an average height of about 1·72 metres. They exhibit few signs of deficiency disease; their skin is usually healthy, their teeth sound and well formed, eye diseases are not common among them. There is not a high incidence of tropical ulcers although some severe cases are seen; scurvy has not been reported among them, but a few Baris present a spongy condition of the gums; two or three cases of pellagra have been recorded. The Baris do not suffer as severely as the Dinkas when infested with hookworms, and only a few children show a severe degree of anaemia; there is a moderate incidence of intestinal bilharzia among them—especially those living along the Nile—but it is not a crippling disease.

The Bari's diet seems to allow him to become a well-developed adult, living a moderately active and healthy life, and to give him fair protection against the effects of the local endemic diseases.

The Latuka and similar tribes, whose country abuts on that of the Bari on the eastern side of the Nile, are a more primitive people; they wear fewer clothes and are, generally speaking, somewhat taller and not so muscular as the Bari. Their main food crops are similar to those of the Bari, but various sorts of millet form a greater part of their cereals and dukhn—the bulrush millet—is but little cultivated. Sweet potatoes are grown in some places, ground-nuts are widely sown, and various beans are also planted. Vegetables form only a very small part of their cultivations, but wild-growing plants (e.g. purslane) and fruits are gathered during the rainy season. The Latuka own a fair number of animals; cattle being common in Liria and again around Keila and as far east as the Kideppo; sheep and goats are more widely distributed. Tsetse fly occur in parts of this country. The Latuka hunt all kinds of game—including buffaloes—but, as most of the water-courses do not flow throughout the year, fish is an uncommon article of diet.

The Latuka usually eat their millet as a thick porridge with soups and sauces, but a good deal of it is drunk as beer. Milk is consumed whenever it is available, also the meat of game animals and goats, whilst many of the villages hold large numbers of chickens.

The Latuka's diet does not seem to be so diverse as that of the Bari. The cereals are fewer in number; the vegetable fats are largely derived from peanuts only; animal proteins and fats from game animals, a few domestic animals, and from milk.

The people themselves are taller and slimmer than their neighbours the Baris and are probably not so robust. They display little evidence of dietary deficiency, but tropical ulcers are not uncommon among them and sometimes present great chronicity.

During the war a company of Latuka soldiers quickly developed cases of early scurvy when forced to subsist for a time on a diet short in vitamin C.

The Madi tribe, who live to the south of the Latuka, are rather more agricultural in their habit of life. They cultivate millet, sweet potatoes, eleusine (*Eleusine coracana* Gaertn.), a little cassava, ground-nuts, sesame, and various beans. They own only a small number of animals, as they live in a sleeping-sickness area and in some years are rather short of food, part of their lands having suffered from soil erosion.

The Acholi, inhabiting the hills on the Uganda border, cultivate a variety of crops: millet, large quantities of sweet potatoes, a little cassava, sesame, and peanuts. They hunt game and also take fish during the dry season. They brew a good deal of native beer and also distil spirits. The Acholi are an active, healthy people and show few signs of disease.

The Mondari, who live to the north of the Bari, are more pastoral in their habits and resemble the Dinkas a good deal in physique and in their mode of life.

The Nyambra, Fagela, Kuku, Kaliko, and Kakwa inhabit the Yei and

Kajo-Kaji districts to the west and south-west of the Bari. Over and above the cereals grown by the Bari, they also cultivate maize (*Zea*), a good deal of cassava, some bananas, and their country also bears many mango trees (*Mangifera indica* Linn.). As a people they are rather more agricultural in their mode of life than the Bari; they keep cattle in some places (as in Kajo-Kaji and near Lui), but goats more commonly and also some sheep.

In physical type these people are shorter and stouter than the Bari, some, indeed, being steatopygous (e.g. the Kakwa). Although they harbour many intestinal parasites, they show few ill-effects and are well developed, active, and of a cheerful, light-hearted temperament.

In the far north-west of this middle zone, that is, along and about the Wau-Raga road, live the Kreish and similar tribes. Here the climate is somewhat drier during the winter months than in most other parts of this middle zone (the average relative humidity is about 35 per cent. in December, January, and February). The nights are cold, the days bright and sunny with a brisk breeze blowing from the north. This weather is then likely to be a stimulant to metabolism.

The main food crops of these people are various millets, eleusine, cassava, ground-nuts, sesame, sweet potatoes, and some maize; they also cultivate vegetables, such as lady's fingers, Jew's mallow, pumpkins, and red pepper (*Capsicum frutescens* Linn.). As this district is within the 'fly' belt, there are practically no domestic animals but only a few goats and some poultry. The women do not eat fowls' eggs. The Kreish are able to secure a little game by hunting and also a good deal of fish; there are a number of watercourses in their country that flow—or hold water—throughout the year. Most of the fish are taken in the months of March and April as the streams are then low and the fish poisons most effective. Honey forms quite an important part of the people's diet; some of it is made into the fermented drink 'duma'.

Millet is ground into flour, cooked as gruel or porridge, and eaten with a sauce or stew. A good deal of native beer is brewed.

These people have a fair variety of cereals and vegetables, and of vegetable fats and proteins. The animal fats and proteins, on the other hand, are short. Cassava leaves and red pepper are much used in their stews and are probably a valuable source of vitamin C during the dry season when other vegetables are not available.

As in many parts of Equatoria Province, there is a local shortage of salt, which is imported and sold in the markets. Potash is made as a local substitute, chiefly by burning millet and sesame stalks, but this, of course, replaces sodium by potassium.

During the year there are two months—May and June—when the people of this district are sometimes actually short of food, whilst the colder winter weather probably demands a higher food intake than in most other parts of the province.

The physical condition of these people, however, is by no means bad; although they harbour many intestinal parasites, yet they apparently suffer few ill effects from such infestation. Frank cases of the deficiency diseases have not been recorded from this area. Here, as in other parts

of the province, a few bow-legged people may be seen, but other signs of rickets are rarely found.

The South-west Area

The third area, that lying on the northern slopes of the Nile–Congo divide, is intersected by many watercourses, covered by thick vegetation and many trees. In it live the Azande and some other tribes, all speaking the same language.

As a measure of sleeping-sickness control these people were gathered together and then set to live strung out along the roads; in the last few years, however, there has been some easing of these control measures and the people are now spreading out into the forest areas.

Soil and climatic conditions in the Zande district permit of the cultivation of many varied crops. The cereals most grown are eleusine, maize, cassava, in some parts a red millet, sweet potatoes, and a little rice. The crops giving vegetable oils are chiefly ground-nuts and sesame; among the vegetables cultivated are marrows, Jew's mallow or lady's fingers; the leaves of sweet potatoes are also eaten. Many fruits also grow in the district: bananas, paw-paws, mangoes, pine-apples, oranges, lemons, and guavas.

The millet is largely eaten cooked as gruel or porridge, whilst a good deal is brewed into native beer. Cassava flour is prepared by soaking the roots in water, drying, and then pounding them into a flour (the soaking removes the poisonous prussic acid). Probably not less than half of the cereals and starchy foods in the Azande's diet is supplied by cassava, which contains very little protein. Vegetable oils are provided by ground-nuts, sesame, shea nuts, and also by a little palm-oil; vegetable proteins are available in fair variety in millet, maize, ground-nuts, and beans. Animal proteins and fats are, however, short as owing to the presence of tsetse fly the Azande do not own domestic animals. They do possess a fair number of chickens, but they probably never eat them but breed them to 'consult the oracle'. The Azande have small dogs, certainly used for hunting, but possibly they eat them as well; game, however, is not common in the district. All manner of small rodents, insects, and termites are eaten.

The rivers abound in fish, and these form part of the Azande diet. The vegetable foods grow freely in the district, and it must be rare indeed to see a hungry person.

Although there is a high incidence of debilitating diseases, such as malaria, hookworm, and bilharzia, yet it is uncommon to find a poorly developed Azande or one suffering obviously from anaemia. Leprosy is a common disease, showing an incidence of about 2 per cent., but tropical ulcers are not common. Endemic goitre also occurs.

The Azande are probably not so short of animal proteins as has been commonly supposed, but they all display 'meat hunger', perhaps more the desire for a luxury than the expression of a physiological need. They make use of honey as a food.

The Azande are generally short in stature—the men give an average height of about 1·69 metres—but they are well-developed and muscular subjects; the women tend to be fat and to approximate to the steatopygous

type. They live an active physical life, are care-free and light-hearted, and exhibit few signs of the deficiency diseases.

There is a high incidence of leprosy among them and they show great susceptibility to poisoning by bismuth (when used in the treatment of yaws), but appear to suffer few ill-effects from infestation by hookworms. In these respects the Azande differ considerably from the Dinkas, as they do also in physical type, and it is of interest to note at the same time the differences in the diets of these two peoples.

Conclusion

A census has been carried out in most of the sleeping-sickness areas, but other vital statistics of the people in Equatoria are lacking.

An impression gained by some personal inquiries—but without figures—did not give grounds to suppose that the abortion rate is high or that the birth-rate is other than the normal for similar African peoples.

Difficult labour, as might be expected in the presence of deformed, rachitic pelves, is rarely seen, if at all.

The new-born child is generally of normal birth weight, length of body, and development. Lactation is easily established and well maintained. There is undoubtedly a high infant mortality rate (although no figures can be given), but the chief killing diseases are malaria and infective gastro-enteritis. Weaning, especially among those with few domestic animals, is without doubt a period of danger for infants, but the danger is mostly from infection; a faulty weaning diet, in itself, is probably only a contributory factor in determining the onset, course, and outcome of infections.

Schoolchildren generally present a satisfactory state of nutrition, although any assessment must necessarily be relative and has no absolute standards. Only about 3–5 per cent. of the schoolchildren are classed as 'below normal' by examining doctors.

The following table of average 'heights and weights' for four small groups of schoolchildren can only give a rough idea of their physical condition (it should be particularly noted that the age is 'estimated').

	Average age	*Height*	*Weight*
Zande District (estimated) . .	15	5 ft. 3½ in.	7 st. 10 lb.
Amadi District (estimated) . .	15	5 ft. 4 in.	7 st. 9 lb.
A sample in U.K.	15	5 ft. 2½ in.	7 st. 4¾ lb.
A sample in Northern Sudan . .	15	5 ft. 2 in.	6 st. 6 lb.

Another sample of schoolboys in the Amadi District giving an average height of 5 ft. 2 in. gave an average weight of 7 st. 1 lb.

When a large number of men were recruited as labourers during the war they were medically examined. Admittedly some 'combing out' had already been done by chiefs, who would not send in cripples or the old and feeble: nevertheless, in one batch of over 1,000 Azande examined, fewer than 5 per cent. were rejected as unfit on account of poor physique, anaemia, or age. About 60 per cent., however, required treatment for such conditions as hookworms, bilharzia, &c. The medical examination

of the other groups also gave satisfactory results of physical fitness for work.

It is uncommon to see really old people in Equatoria Province, but there is, of course, no known expectation of life, nor are the causes of death in old age known.

In conclusion it may be said that, living on food available to him in his environment, the native of Equatoria Province usually grows to a reasonably well-developed adult, lives a fairly active physical life, and, as far as is known at present, appears to reproduce himself at a rate at least to maintain his population.

The South-east Area

At the other end of the province, at its south-eastern corner and in the angle formed by the Sudan frontiers with Abyssinia and Kenya, live the Toposa. They are a pastoral people and their country, which is far more sandy than most other parts of Equatoria Province, provides conditions near those of the desert during the dry season of the year. The Toposa cultivate some dura millet, a little maize, and also some bulrush millet; they own a large number of domestic animals—cattle, donkeys, sheep, goats, and poultry. They seem to grow very few vegetables, but gather wild plants and fruits during the rainy season. A little native beer is made from millet.

They drink much milk, to which is commonly added fresh blood drawn from their animals, the mixture being boiled before use. Meat is not often eaten, but game animals are hunted.

The diet of the Toposa is rich in animal proteins and fat, appears to be short in carbohydrates and also in fresh vegetables and fruit at certain times of the year.

Tropical ulcers occur among the Toposa and some cases of scurvy have been recorded; they are, however, generally speaking, a tall, well-developed people living an active physical existence.

THE PROBLEM OF NUTRITION AND TRIBAL DIET FROM THE AGRICULTURAL POINT OF VIEW

By J. D. TOTHILL, C.M.G., D.SC., B.S.A.
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The question of nutrition is of profound interest to administrators concerned with the wise and beneficent government of tribes the social emergence of which has not yet taken place; to the medical profession concerned with maintaining and improving the health of these tribes; and to the agricultural profession concerned with modifying the production of animals and plants so as to make balanced diets possible. Lorenzen and Corkill have referred to the medical aspects of the subject as affecting Equatoria Province and the Sudan as a whole, and it may be of interest to refer to some of the agricultural facets of the same problem.

The subject is large and difficult. There are personal tastes and food prejudices sometimes supported by tribal taboo or custom that may make it impossible to introduce the best food to counteract a particular deficiency. It is not sufficient to analyse the possible range of foods chemically because vitamin content may be more important than proteins or fats or carbohydrates or minerals or calorie value; and vitamin content can only be obtained by slow methods of computation based in the main on feeding tests. Neither is it sufficient to apply, for example, a *Sorghum* millet analysis done, say, in the Punjab, to varieties grown in the Equatoria Province of the Sudan. Again, there are many minor foods and flavourings used by Sudanese tribes that have not been analysed at all and the vitamin content of which is unknown. In this list are wild fruits; wild herbs used as salad or vegetable or flavouring; amphibious snails such as *Ampullaria*, *Lanistes*, *Pila*, and three species of the land snail *Limicolaria* that abound locally; and insects of several sorts, but particularly newly emerged termites of several species. It is possible that some of the deficiencies indicated by examination of the value of the main foods in any particular area may be made good by the use of some of these minor foods and flavourings. Finally, there is the difficulty of making proper allowance for heredity when assessing the nutritional value of foods consumed, for instance, respectively by the long-legged Dinka and the short, stocky Azande.

Despite these difficulties, however, progress is being made. The 'Note on Nutrition in Equatoria Province', for instance, by Dr. Lorenzen shows that although we know so little about some features of the problem some very important steps have none the less been taken in the last 30 years towards solving it by the method of agricultural diversification.

Lorenzen stresses the value to-day to many tribes, in Equatoria Province, of the following foods. The ground-nut (*Arachis hypogaea* Linn.), now a normal source of vegetable oil for a large proportion of the population; the sweet potato, the roots of which supply starch and many minerals, and the leaves vitamin C, to a large proportion of the population; maize, which supplies starch and, when young, some sugar to an ever-increasing number of people; cassava, the best drought-resisting crop known to tropical Africa, the roots of which supply starch and the leaves vitamin C to fully half the population of Equatoria Province; and the ubiquitous fruits of the wetter parts, the mango and the pawpaw. The interesting point about these crops is that they are without exception introductions either from America or from India, and that their wide distribution in Equatoria Province represents a substantial achievement in agricultural crop diversification. This policy still goes forward in Equatoria Province, and two more introductions, sugar-cane and oil palms, will soon come to be grown widely in Zande, Maridi, and Yei districts.

In the matter of animal proteins the meat hunger of the Azande people is being dealt with experimentally by the sale of dried meat from the Dinka country, and the Zande development scheme will enable the matter to be pursued to finality. While proof is lacking, it has not been disproved that there is no connexion in the tropics between meat deficiency and leprosy, which without any apparent connexion linger on together in

important parts of the tropics as widely separated as Zande land and Fiji. They are problems that remain to be resolved.

Crop diversification and milk and meat production are also recognized policy in all parts of the Sudan where it is practicable to implement it, and many examples are given in this volume. In the chapter on Darfur, for instance, some details are given about diets in the Jebel Marra area and the recent addition of fruit and vegetables. In the chapter on land fractionation particular reference is made to the agricultural aspects of the nutrition problem at Nuri and at Bouga: and in the chapter on Northern Province there is a refreshing picture of steps taken at Aliab, Bouga, and the Government pump-schemes generally to provide the wide range of foods both animal and vegetable that the medical profession has shown to be necessary.

The problem of nutrition is particularly difficult to solve in Blue Nile, Kassala, and Upper Nile Provinces, where vegetables and fruits are difficult to produce and where milk supplies may be unequal to the demand. The Soil Conservation Committee[1] addressed itself to the general question of the reclamation and control of village peripheral areas and made a number of important recommendations designed to improve the milk and meat supply by the provision of adequate grazing areas. These recommendations were accepted by Government and are being carried out gradually. The task is immense, but as the villages in the Sudan are gradually redesigned a substantial improvement in nutrition will inevitably follow.

In areas liable to partial famine through lack of rain or through attack by locusts the problem of nutrition can generally best be solved, or reduced to reasonable proportions, by introducing into the normal rotation crops that have special value in the war against famine. Of special merit as locust resisters are the spreading as opposed to the bunch types of ground-nut, sweet potatoes, cassava, and maize. Cassava is by far the most reliable famine reserve crop because the bitter kinds produce high yields of tubers that may be left in the ground for about 4 years. Maize yields a crop in a very short time and may become in emergency an extremely useful stopgap. While neither cassava nor maize are ideal foods they are both on occasion invaluable in securing protection against, or rapid recovery from, famine.

In remote areas the problem of nutrition differs from that in central areas and particularly in towns well served with communications. To give an example, cod-liver oil is a good source of vitamin A; a little goes a long way; it is relatively inexpensive and can be used economically as a protective food in any town in the Sudan served by the Railways and Steamers Department. It would, however, be expensive and impracticable to use cod-liver oil generally in the Zande or Maridi districts. In these remote areas it is necessary to find a substitute that can be obtained from rivers, lakes, animals, crops, or productions of the particular area and that can be made available to the humblest citizens living in the remotest isolation. In this particular example, for instance, the growing

[1] See report of Soil Conservation Committee published by Sudan Govt. 1944.

of oil palms may prove to be the best answer to the vitamin A deficiency problem.

Finally it may be said that while the provision of satisfactory tribal diets enters strongly into the agricultural policy of the Sudan and that, through planned diversification of crops and the encouragement of milk and meat production substantial improvements have been made, yet a great deal more factual information about food deficiencies is required as a preliminary to enable the problem of nutrition in its infinitely varied forms, between the Sahara and the tropical rain forest, to be resolved in the most intelligent manner possible in each area.

SECTION II

CHAPTERS DEALING WITH AGRICULTURE AND FARM ANIMALS

Chapter XV

CROP PRODUCTION

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Introduction

ELSEWHERE in this book will be found detailed descriptions of the numerous and varied assortment of crops grown in the Sudan. This chapter does not attempt to deal with all the methods used for producing those crops in each district; but an attempt is made to set out in general terms the normal methods of crop production, as well as describing some of the more unusual, but at the same time very important, methods adopted for particular purposes or undertaken by certain tribes through force of circumstances. The Sudan is a vast country embracing some one million square miles of territory, and in this enormous tract the wide variation in climatic conditions is reflected in the diversity of crops and the methods by which they are produced. Generally speaking, the main factor influencing production is the amount of the rainfall, although north of the 18th parallel and extending to the Egyptian border rain is practically non-existent and cultivation is almost exclusively confined to a narrow strip along the banks of the Nile where irrigation methods can be practised.

Implements in Use

Before we can understand a description of the methods used in crop production we must know something of the implements or machinery employed for this purpose. Throughout the greater part of the Sudan all cultural operations are undertaken solely by manual labour, and it is only in the northern Sudan, where intensive cultivation is practised, that animal or mechanically drawn implements are seen to any extent. The following notes on the more common implements (though not by any means a complete list) will help the reader to understand the various methods of cultivation afterwards described.

(*a*) *Hand Implements*

Although there is a good variety of implements of all shapes and sizes peculiar to different districts, the main implements in all districts are fundamentally the same and consist of a hoe, an axe, some sort of a knife for harvesting, and a forked stick for use as a rake.

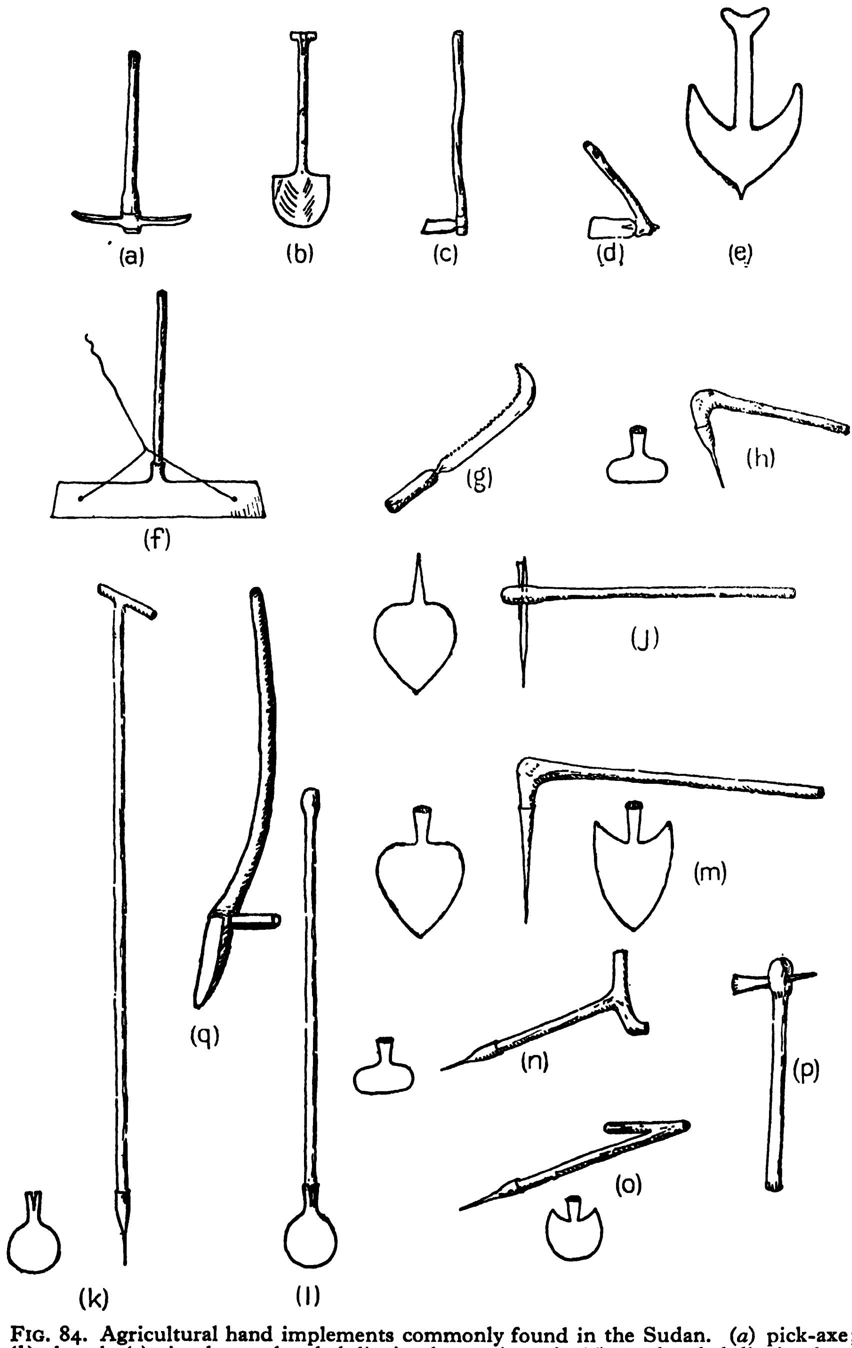

FIG. 84. Agricultural hand implements commonly found in the Sudan. (*a*) pick-axe; (*b*) shovel; (*c*) simple two-handed digging hoe or 'torea'; (*d*) one-handed digging hoe; (*e*) short 'malōd'; (*f*) flat-faced levelling board earth scoop or 'wasūq'; (*g*) sickle; (*h*) short-handled digging hoe fitted to an elbowed branch; (*j*) locally made digging hoe with sharp-pointed fixture on blade; (*k*) long-handled weeding hoe or 'malōd'; (*l*) short-handled weeding hoe or 'malōd'; (*m*) short-handled digging hoe mounted on elbowed branch; (*n*) short-handled weeding hoe used from a crouching position; (*o*) another version of the above; (*p*) a native-made axe; (*q*) a digging stick or 'selūka'.

A brief description of the main types follows; see also the illustrations in Fig. 84.

(i) *Digging Hoe* (*'Torea'*[1] *or 'Fas'*). This is a double-handed hoe shaped like an adze and, in one form or another, is in common use everywhere (Fig. 84 (*c*), (*d*), (*h*), (*j*), and (*m*)). Many of the hoe blades are of European manufacture and have a socket hole for the handle, which may also have been imported from Europe. The handles are 3 to 4 ft. long and the man, when using the 'torea', remains practically upright. When the hoe blades are made by local blacksmiths one end of the blade is generally

FIG. 85. Fūr man using the short-handled native hoe (*photo E. N. Nightingale*).

extended into a narrow point which is thrust through a previously prepared hole in the top of the handle (Fig. 84 (*j*)). Local handles are cut from any tree or shrub yielding a strong wood and generally consist of a side branch with a swelling at one end into which the blade is fixed.

(ii) *Small Digging Hoe* (*'Kadunka'*). This is of roughly similar pattern to the 'torea', but has a much shorter handle and the man using it has to stoop constantly. The blades are nearly always of local manufacture and may be sharp-pointed or square-edged like a 'torea'. They are secured to the shaft by being forced through a hole in the knobbly end, as with locally made 'torea' (Fig. 84 (*d*)).

The same type of implement is procured by fixing a similar type of blade into the point of an elbow-shaped branch (Fig. 84 (*h*)). Both the length of the main branch and the length of the secondary part beyond the elbow vary considerably, but the implement generally more nearly

[1] The word 'toria' or 'torea' is not Arabic and seems to be a Nubian survival from pre-Arabic times. Mr. Mynors informs me that in the Nubian language the word for hoe is 'toreh' (pronounced tor-ray). For comparison the equivalent word in the language of Dongola is 'tobro'.—*Editor.*

resembles a 'torea' than a 'kadunka' as the worker can dig in an upright position.

(iii) *Weeding Hoe ('Malōd' or 'Malōda': also called 'Hashshāsha').* Resembles a Dutch hoe, but the actual size and shape of the blade varies in different parts of the country (Fig. 84 (*k*), (*l*), (*n*), (*o*)). The most common type has a segment-shaped blade with the curved edge outwards and is about 10 in. across. Others, such as the Madi hoe, are more elaborate. The simplest type, which is very general in Equatoria Province, consists of a flat disk of soft iron 4 to 7 in. in diameter. The blade may be fitted to

FIG. 86. Mandari hoeing with short hoe. Always done in squatting position. Equatoria Province (*photo J. F. E. Bloss*).

a long handle up to 10 ft. long, or to a short handle; in the latter case the hoe is used from a squatting or kneeling position (Fig. 84 (*n*) and (*o*)).

In Kordofan the 'malōda' is set at right angles to a long handle and used for sowing. This is known as a 'sallūkāb'. The cultivator walks backwards drawing the 'sallūkāb' towards him, thus making a series of shallow holes for sowing purposes.

(iv) *Sowing-stick ('Selūka').* Consists of a wooden stick with a slightly curved and flattened, pointed end. This is forced into the ground by means of a projecting foot-rest and the stick rotated to produce a hole for sowing (Fig. 84 (*q*)).

Other types of sowing-sticks are used in different parts of the country and it is quite common to find a spear-head used for this purpose. In the White Nile area the local type of sowing-stick, called a 'karbōl', resembles a long dibbling-tool. The main stick is about 1 metre long with a handle at the top and sharp-pointed at the bottom.

A less common type of sowing-stick called a 'mohfar' looks like a 'torea',

but the iron head is long, narrow, and pointed. Seed-holes are made by a digging action.

(v) *Axe* (*Fas*). Used for clearing scrub, and is generally a very primitive but practical implement made from a wedge-shaped piece of soft iron and weighing about 2 lb. The broad end of the wedge is ground to an edge, while the other end is pointed and forced through one end of a short handle procured from a suitably strong local tree (Fig. 84 (*p*)).

A better type of axe-head manufactured in the bigger towns has a socket into which the handle is set.

FIG. 87. Hoeing rain-grown dura with the 'malōda'. Gezira area (*photo G. J. Fleming*).

(vi) *Shovel* (*'Korēq'*). Not extensively used except on the larger estates and for Government work. Any light European type may be in use (Fig. 84 (*b*)).

(vii) *Sickle* (*'Mungal'*). A short saw-edged blade, fitted to a short wooden handle (Fig. 84 (*g*)). Used for cutting grass, forage crops, and grain.

(viii) *Short-handled Weeding-hoe* (*'Nigam'*). Consists of a very small blade, up to 3 in. in diameter, fixed to the end of a short handle (Fig. 84 (*n*) and (*o*)): it is always used from a squatting position.

(ix) *Rake* (*'Birāza'*). Generally consists of a forked branch from a tree with prongs about 6 in. long.

(x) *Harvesting Knife* (*'Sikkīn'*). For cutting dura the commonest implement is the double-bladed knife which is carried on the arm in a sheath.

Another type of knife used for the same purpose and called a 'sekab' consists of a piece of iron like a 'malōda' head sharpened along one edge. No handle is attached, the whole piece of metal being grasped in the harvester's hand.

The name 'sekab' is also applied to a very light axe used for cutting out 'qassab'.

Syndicate, on the other hand, rely extensively on mechanically drawn implements, and their ploughing-tackle unit consists of two 60-B.H.P. McLaren-Benz Diesel engines drawing one combined cultivator and multiple ridger (cultivator 8-tined, ridger 5-furrowed).

Cultural Operations

No general rules applicable to the country as a whole can be laid down regarding normal methods of cultivation. Where land is farmed intensively, as under systems of irrigation, or in the western part of the Dinka area, where there is a definite shortage of land suitable for cultivation, great care is taken of the crops. The land is well worked before sowing and a good seed-bed prepared; it may be manured, and subsequent weedings and cleanings are normally well carried out. In the areas of rain cultivation, however, where land is not a limiting factor, casual and indifferent cultivation is common, and the vast area of land available has not tended to make farmers careful of the natural resources of the soil.

Before sowing takes place and before any attempt is made at cultivation the land is cleared of bush and trees. Trees are seldom uprooted, but are normally felled about breast high, the implement used being the small-bladed and comparatively light axe referred to above (Fig. 84 (*p*)). Larger trees may be ringed in the autumn and then either felled or burned down when they have dried out. All branches are then burned and the ashes scattered. Except in specialized cases the land is cleared of grass and weeds before sowing by hoeing and burning and a more or less clean seed-bed prepared to receive the seed. The hoeing, however, is a mere scratching of the surface and is not comparable to any form of ploughing.

If sowing is to be done on the flat, as is usual, no further pre-cultivation is undertaken. Certain crops (chiefly irrigated cotton) are sown on ridges and, where this is the case, the land is ridged up by means of a ridging plough just before sowing takes place.

Sowing

Practically every crop throughout the country is sown by one of three methods.

(i) *Broadcast.* The usual method for small-seeded crops and is more common with rain cultivation than on irrigated land. After the seed has been scattered it may be lightly covered by brushing with a branch or by raking with a forked stick. In certain districts the seed is sown before the old grass has been removed, and the seed then gets covered in the process of removing the grass.

(ii) *By 'Torea'.* Used when seeds are sown in individual holes. Generally a man walks in front making the holes with a 'torea' and a woman or child follows behind dropping a few seeds into the hole and then covering the seeds by scraping earth over them with the foot (Fig. 92). In place of a 'torea' any of the sowing or cleaning implements mentioned above may be used.

(iii) *By 'Selūka'.* This method is in every way similar to (ii) above, but in place of a 'torea' a 'selūka' stick is used (Fig. 90).

FIG. 90. Sowing cotton by 'selūka' in the Gezira
(*photo F. Crowther*).

Whichever of the above methods is employed seed may be sown either pure or mixed. Frequently beans are sown along with dura in the north, while in the rain areas of the south dura and sesame, or eleusine and sesame, or maize and beans are common mixtures. When a crop is sown pure it is a common practice to include in the seed mixture seeds of different varieties of the same species. This almost certainly ensures that a crop of some sort will be reaped whatever the climatic conditions may be.

Weeding

All weeding is done by one of the iron-headed tools described above: 'torea' or 'malōda' type. Frequently the workers squat or sit while weeding, especially when using one of the very short-shafted imple-

FIG. 92. Sowing bulrush millet (*Pennisetum tyhoideum*) near Nyala, Darfur Province (*photo E. H. Nightingale*).

ments. It is usual in the north to refer to weeding as hoeing, and when a crop has been twice cleaned it is referred to as having been hoed twice. Animal drawn horse-hoes are only used in the cotton areas.

Bird Scaring

In most districts, if grain crops were not protected from birds (chiefly weavers, sparrows, finches, and pigeons) probably half the crop would be destroyed. The normal method of protection is to build a scaffold 10 to 15 ft. high with a platform on top and on this platform to post children whose job it is to scare away birds. From dawn to dusk someone is always on duty slinging mud pellets, shouting and cracking whips, or pulling one end of a rope to the other end of which is attached a jangling can. These methods of protecting crops from the depredations of birds can be most effective.

Harvesting and Threshing

The particular methods employed to reap and thresh individual crops are described in the chapter 'The Crops of the Sudan'. It may be said in general, however, that except for a knife, or other sharp-cutting instrument such as a spear-head, which is used for cutting off heads of grain crops, no special harvesting implements are used. In the harvesting of grain the stalks are cut close to the head and the heads are then carried either direct to the threshing-floor or to a storage hut to dry out. Grain

FIG. 93. Fūr bringing wheat to threshing-floor. Jebel Marra, Darfur Province, height 6,000 ft. (*photo E. H. Nightingale*).

is normally threshed before storing, but in the areas of rain cultivation the weather at time of harvest may be too wet for threshing: in such cases threshing may have to be delayed for 6 weeks or 2 months after the heads have been cut.

The recent introduction of wheat-growing on a large scale as a war-emergency measure has produced an abnormal situation and to cope with this development threshing plants have been used.

Threshing (Figs. 93–6) is normally done with a flail or spear shaft, or with an implement rather like a cricket bat, on a specially prepared threshing-floor about 8 yards in diameter. This floor may be nothing more than a cleared area of well-beaten earth, or it may consist of a mixture of mud and cow-dung allowed to harden and dry off. After threshing the grain is cleaned of dirt and chaff by being poured from a basket held head high and allowing the wind to do the winnowing (Fig. 112).

Storing

Grain, and particularly dura, is the only crop which is normally stored

FIG. 94. Für children threshing wheat at Suni, Jebel Marra, height 6,000 ft. (*photo E. H. Nightingale*).

FIG. 95. Baka women, south of Maridi, threshing grain (*photo J. F. E. Bloss*).

for any length of time. As dura is the staple food of the country, reserves may be stored for 2 years or more and there are two recognized methods of storage, i.e. in pits below ground, or in containers above ground.

In the areas of light rainfall the usual method of storage is in circular pits. These pits are called 'matmura' and may be of any size, ranging from a capacity of 10 ardebs up to 150 ardebs. The most common size of 'matmura' contains 15–20 ardebs. Certain types of soil are more suitable than others for the construction of 'matmura'. The best soil is one of fairly close texture and with good natural drainage.

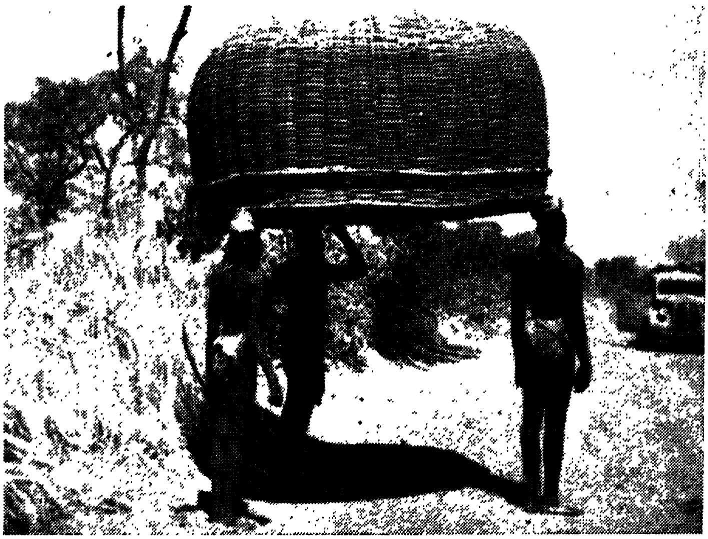

FIG. 96. Moru natives carrying their grain-store. Equatoria Province (*photo J. F. E. Bloss*).

When the hole has been dug the dura, which must be bone-dry, is filled in until within 9 in. of the top: the threshed heads are then laid on and the last 6 in. filled with earth which is continued about a foot above the level of the ground, in order that the rain-water may run off.

Recently, through force of circumstances, it has been necessary in the north to store dura and wheat unsacked in the open, on specially prepared platforms. Loss from rain, birds, dirt, &c., has been surprisingly light, damage by weevil and moth has been insignificant, and this method of storage may survive the present emergency.

In the south, where 'matmura' cannot be used owing to the fear of water seeping into the pit, and in Dongola where underground storage cannot be used on account of white ants, grain is stored in specially prepared containers. These may be of mud or made of grass or reeds in the form of large baskets and normally do not contain more than 20 or 30 ardebs. The outside is usually plastered with fermented dung as a protection against the rains. These stores have different names in different parts of the country, but the most common ones are 'suēba', 'gugu', and 'kōk'. If the store is raised off the ground it may have collars of thorns or

mud round the legs to keep out rats; or it may be built over the kitchen or cook-house, so that the smoke and heat enters the store and preserves the grain. All storehouses, after being cleaned out, are smoked.

Maize is stored in the cob by hanging on racks or on trees.

Figs. 96–100 show typical grain stores.

Seed Selection

As with storage, seed selection of food crops is mainly confined to dura, but it cannot be said that any form of seed selection, even of dura, is general throughout the country. Most selection is done with the early maturing varieties, and here selection is made for size of head and quick maturing characteristics. Occasionally seed for the whole cultivation may be selected from a small plot which has been specially manured. Seed grain is stored in the ear and is generally hung in the dwelling-house where it is protected by smoke.

Recently seed-saving clubs have been formed in Northern Province, and though this is not exactly seed selection it is a method of ensuring that every member of the club will have sufficient seed when sowing time comes round.

Weed Control[1]

As distinct from normal weeding, certain weeds or grasses require special control methods. With rain-grown crops very little special control of this nature is undertaken, beyond moving on to fresh ground when any particular weed has become troublesome. On irrigated land, however, or under conditions of intensive cultivation, strict control measures are essential and the following give much trouble in many districts:

(*a*) *Addar grass* (*Sorghum* spp.). When possible the land is pre-watered to encourage germination, then ploughed and worked down before the crop is sown.

(*b*) *'Dīs' or 'seid'* (*Cyperus* spp., mainly *C. rotundus* Linn.). A very troublesome sedge in the Gezira and in the Gash Delta where different methods of control are practised. In the Gezira frequent deep ploughings or deep disk cultivation are undertaken. In the Gash attempts are made to kill the grass by preventing flood-water reaching badly affected areas for a period of 6 years. Much of the effect of this is wasted on account of rain, but some success has been achieved.

Agricultural Methods

A very large proportion of the crops of the Sudan are grown in the areas of heavy rainfall and these crops are entirely dependent on the rains for their water-supply. North of the rain-belt irrigation in one form or another is necessary for crop production, and it is in these irrigated areas that the most intensive forms of agriculture are practised.

Irrigated Crops

Irrigation as seen in the Sudan takes many forms and is not merely a

[1] For more details see the article 'Weeds in the Sudan', Chapter XVII.

grow easily, the population is indolent and cultivation is limited to the individual needs of the people.

Light Rains

In the areas of light rainfall (i.e. 10 to 15 in.) crop production dependent on rain alone is very much of a gamble, but it is usual to find that limited areas have been sown. Crops so produced are regarded more in the nature of catch crops and are not relied upon for producing the main food-supply of the district. If it is desired to make the best use of the very limited amount of water obtained in these areas of light rainfall the ground must be fitted with low earth banks or 'terūs' along the line of the contour (across the slope of the land) to hold up the surface rain-water and prevent it from running to waste (Figs. 88 and 107). The lower end of each 'teras' is more heavily irrigated than the upper end, and is thus more productive. Only quick-maturing crops are grown on these areas. When the crops begin to show signs of thirst frequent hoeings are given, as these help to conserve the moisture.

Other areas which are usually cultivated in this zone of light rainfall are the wadis or khor beds. In Shendi district and in the Butana this wadi cultivation is on a considerable scale and plays an important part in the crop production of the districts.

Heavy Rains

The main areas of cultivation are found in the zone of heavy rainfall. Where the rainfall averages between 15 and 30 in. great tracts of dura are to be found, as well as of dukhn, sesame, and possibly cotton. The systems of cultivation employed are varied but practical and are described later in this chapter.

Grain crops are divided into 'early' and 'late' and each has its own peculiarities. The early-sown grain is a quick-maturing variety which ripens in 2½–3½ months. This is normally sown immediately after the first good rain of the season, but in some districts and especially with nomadic tribes it may be sown before any rain has fallen at all. In this way a very early crop may be obtained in a good year, but it is a 'hit or miss' gamble, and as likely as not no yield at all will be obtained.

The commonest cause of failure is a rain sufficient to cause germination but insufficient to support early growth. The grain reaped from these early duras is not stored but is eaten at once. The crop is harvested in July and August, when the majority of the farmers are probably hungry, having by then consumed all the old dura. The early maturing duras are thus a stopgap, and provide grain for the three months of the year when normally no other grain would be available. These early crops are generally sown round or near the houses where they can get more attention, and they often receive a certain amount of manure from household refuse, ashes, &c. After cutting, many varieties of early maturing dura will produce a ratoon crop, and this second crop is frequently of great importance locally. The ratoon crop may be harvested in the year of sowing or, in the south, the roots may lie dormant during the winter and not produce the second crop until the following year.

The late-sown crop consists of slow-maturing varieties which may take up to 7 months to ripen. These constitute the main grain crops of the district and are not sown until the rains have been well established. The slow-maturing duras are seldom sown round the houses but are always grown on the best available land, which may be several miles away from the villages.

Systems of Rainland Cultivation

(1) *Shifting Cultivation.* With land practically unlimited and certainly far in excess of any demand which could be put upon it, except in special localities where a definite land hunger exists, the normal agricultural method employed is one of shifting cultivation. Under this system certain areas are brought under cultivation for a time, and then the farmer moves to new ground, preferably untouched or virgin forest. After a few years the process is repeated. One man may work several such farms, each of which may be under a different crop. The farms may be widely scattered in the forest and generally average about 2 feddans each. By this system a primitive type of crop rotation is practised. After a particular area in the forest or bush has been cleared for cultivation the ground is sown year after year with the same crop until disease, or a greatly reduced yield, forces the owner to move elsewhere. The move consists in clearing an adjoining area of forest, and so the process goes on until the original farm, through having been allowed to go back to nature and thus regain most of its old fertility, will once more be brought back into cultivation. The main crop to be grown throughout this period will be grain of some sort, but the first crop sown on newly cleared land may be a subsidiary crop: this may be ground-nuts or sesame, depending on the district. Before finally abandoning an area another subsidiary crop will be sown which may be a one-season crop or may possibly be cassava which will remain in the ground for 2 or 3 years before being dug up. As the area of cultivation shifts so may the houses, but it is more usual for the houses, probably sited near a domestic water-supply, to remain permanently in one place.

This system of shifting cultivation, or leaving it to nature, has several advantages which may not appear obvious at first glance. After the soil has been exhausted through continuous cultivation the farmer simply allows it to return to bush or grass until it gradually regains most or all of the fertility which it had lost. This is much simpler and easier than sowing a leguminous crop and later digging it in.

Another advantage is the control of disease and insect pests which is automatically imposed through the constant shifting of the farms. With small scattered farms never long in one place and often separated by areas of thick forest the chances of disease causing severe damage are much less than when crops are grown in large blocks.

As the farmer frequently returns to his original clearing, after a spell of anything up to 12 years and cleans the bush which has grown up, shifting cultivation is therefore a modified form of crop-rotation with a long resting-period.

The great disadvantage of shifting cultivation is its wastefulness.

Probably five times as much land is required to grow a given quantity of crop as would be required with more modern methods. Only one-fifth of the total cleared area is under crop at any one time. The remainder is in various stages of natural regeneration. The continual burning of the cleared bush has also a cumulative bad effect on the land, through the destruction of great quantities of valuable humus and of vegetation.

(2) *Harīq Cultivation.*[1] As with shifting cultivation, 'harīq' cultivation can only be practised where the available land far exceeds the demand. In this case it is not forest land or bush which is required but rich clay plains on which a thick growth of strong and long grass is found.

The underlying feature of the system is to allow controlled burning to do the work of cleaning the ground for cultivation and reducing subsequent weedings. This very considerably reduces working costs, and at the same time produces excellent yields. The normal procedure is to allow 2 to 4 years' growth of grasses to form a rank dense matted growth. After the first heavy rains in the year chosen for cultivation and when the new growing grass has sprouted and is showing green, the matted growth is fired. If taken at the right time the heat generated from the burning dry grass is sufficient to kill off the new young grass. The resultant clean land can then be sown, and if the burning has been successful no subsequent hoeings should be necessary.

This type of controlled burning is very different from the uncontrolled fierce hot fires which sweep the country during the dry weather. In fact good 'harīq' grass is rather difficult to burn properly and only certain grasses are suitable for the purpose. Tufted grasses are unsuitable, and for good 'harīq' cultivation a thick mass of grass untrampled by cattle is essential.

This form of cultivation may be employed on land which has been cropped previously and left to recover. The time allowed for the regeneration and growth of grasses is roughly proportional to the length of time the land has been cropped. If the cropping has been for 1 or 2 years only, then 'harīq' grass may grow after 1 year's rest, but if the land has been cropped for 4 years, suitable 'harīq' grasses may take up to 4 years or more to form the requisite dense mat. The ideal accumulation of grass is stated to be a 4 years' growth, but this is probably seldom attained. A mat of old grass makes for a cleaner bed, but serviceable 'harīq' can be obtained from the growth of one bumper grass crop, and owing to the universality of annual fires this often has to serve. A bed of old grass is highly prized and in the Gedaref and Fung areas is called 'wad lebūn'.

Harīq Grasses and their Protection. Far and away the best 'harīq' grass is *Sorghum purpureo-sericeum* Aschers and Schweinf. ('anīs' or 'bigil'). Other important 'harīq' grasses are *Aristida mutabilis* Trin. and Rupr. ('dumbalab'), *Hyparrhenia pseudocymbaria* Stapf ('umm ritsū' or "ansora') and *Brachiaria obtusiflora* Stapf ('umm chir'). Other satisfactory 'harīq' grasses but ones which are less widely distributed on good clay soils are *Pennisetum mollissimum* Hochst ('dukn misikhat'), *Rottboellia exaltata* Linn. f. ('umm belila'), and *Cymbopogon nervatus* Chiov. ('nā'al'). This latter grass gives a clean bed, but is not at all amenable to protection.

[1] *Harīqa* means in Arabic 'conflagration' and 'harīq' cultivation might equally well be called cultivation with the help of fire.—*Editor.*

FIG. 97. Building Zande grain-store, Equatoria Province (*photo J. F. E. Bloss*).

FIG. 99. Latuka houses and grain-stores. Note bee-hive made of plaited reeds. Equatoria Province (*photo J. F. E. Bloss*).

FIG. 100. Mandari house and grain-store near Terakeka. The crop is dura. Equatoria Province (*photo J. F. E. Bloss*).

The protection of 'harīq' areas is an important village obligation, and various methods are adopted to preserve the grasses from being prematurely burnt. The hot grass and forest fires which rage during the dry winter months are a source of great danger to the 'harīq' grasses which, if burnt at the wrong time, may cause serious financial loss and food shortage to the whole community. The most efficient method of protecting the 'harīq' areas is to cultivate a strip about 100 metres wide right round the 'harīq' preserve. Clearing fire lines is somewhat similar, and a third method of protection is afforded by burning off the short grass on the surrounding non-'harīq' ground. This must be done early, before the long grass on the clay plains has dried out.

In districts where 'harīq' cultivation is practised (Kordofan, Blue Nile, Kassala, and Upper Nile provinces) most farmers like to have at least part of their land cultivated by this method every year.[1]

(3) *Intensive Cultivation.* In districts where suitable land is restricted neither shifting cultivation nor 'harīq' cultivation is possible. These restricted areas are mainly in the neighbourhood of towns, or in rural districts where a sudden influx of population has upset the normal economy. In such districts continuous cropping of the same land is resulting in greatly reduced yields and a serious problem is arising or has already arisen. In places the only solution is mixed farming with ample applications of manure and then more manure, but the day is not yet when the farmers of the Sudan are ready to adopt more advanced and less wasteful methods of farming. Meanwhile the soil deterioration continues and the eventual reclamation will be no easy job.

The present systems of cultivation on these over-cropped areas are many and various, but if even reasonably good crops are to be obtained much hard work is necessary. Typical methods of good farming employed in the restricted areas are:

(*a*) Mixing a leguminous crop, usually 'lubia helu' (*Vigna unguiculata* Walp.), with the dura crop. This helps greatly to reduce the soil exhaustion produced by continuous dura.

(*b*) Instead of 'lubia', sesame may be mixed with the dura. This produces an effect similar to an ordinary rotation of crops.

(*c*) Continuous mulching may be practised. The grass and weeds, after hoeing, are left lying on the ground to rot and so provide a little much-needed humus.

(*d*) By sowing dura at wide spacings each plant has room to develop and the best use is made of the available food in the soil.

(*e*) After harvesting, the dura stalks are cut and left lying on the ground. These get broken down by termites and so provide another source of humus.

(*f*) Finally, whatever aids are enlisted, the main factor in producing fair crops annually for many years on the same land is hard work. Thorough and continuous cleaning of weeds is essential.

Specialized Methods

The three methods of rainland cultivation described above are found

[1] For further discussion of 'harī'q cultivation see pp. 489 and 490.

in operation everywhere throughout the rain belt. They are the normal methods of crop production under rain conditions. In one or two places, however, more specialized methods are found; introduced, no doubt, through force of circumstances. Two of those methods which are of particular interest, and both of which are practised by the Dinka of Equatoria Province, are worth describing:

(*a*) *Termite and Branch Cultivation.* By this system termites are used for rejuvenating worn-out land required for cropping and it is really a development of method (*e*) described above under 'intensive cultivation'. The plot of land to be rejuvenated is covered to a depth of anything up to 2 ft. with a mulch of tree-branches to which the leaves are still adhering. These branches may have been cut from trees situated in the immediate neighbourhood of the plot, or they may have been carried from trees growing a considerable distance away. After the mulch of branches has been spread the plot is generally protected against goats by a small prickly barrier laid round it. In due course the leaves drop off the branches, the branches themselves are rendered into dust by termites, and by the end of the dry season the plot is once more ready for cultivation. Land badly affected by sheet erosion and unable to support a grass cover becomes, after this type of treatment, fertile in the space of about 4 months. Although the effect of this termite action in rejuvenating the land is undoubted and rapid it is not certain whether the improvement can be attributed to a true manurial process or whether it is due to a sort of earth-worm farming in which termites instead of earth-worms perform the work of the soil aeration.

This system of allowing termites to break down vegetable matter is not confined solely to the Dinka. Many other tribes follow the same practice, but on a smaller scale, and probably confine the spreading of branches to material cleared off the ground actually to be cultivated.

(*b*) *Tethering.* This is perhaps more a method of manuring than a system of cultivation, but as the process is an involved one and embraces more than the actual manuring of the land it may fairly be described here. It is practised intensively in one district only—by the western Dinka of Aweil district—but is of great importance locally, and as the general principles of using cattle manure for improving the land are so little understood elsewhere modifications of the system could be introduced to other cattle-owning tribes with great advantage.

The basic feature of the system is the close tethering of cattle at night on the land required for immediate cultivation. In this way the soil receives considerable quantities of dung and urine which have been voided during the night and its fertility is maintained despite continuous cropping.

The conditions under which the western Dinka live is no doubt responsible for the development of this unique system of Sudan farming. The land available for growing crops is very limited indeed and consists of a number of 'islands' of varying sizes emerging from the 'toich'. On these 'islands', comprising the drier portion of the flood plains, the Dinka villages have been built, and these are in all respects permanent villages. The cultivated land is therefore in close proximity to the villages, and there is so little of it that it would long ago have been played out but for

this complete and conservative system of mixed husbandry which has been evolved.

During the latter part of the dry season the Dinka cattle are found grazing far from the villages on the winter grazing-grounds. At the approach of the cultivating season in May the herds are driven back to the villages and split up amongst their various owners, who tether them on their cultivations at night before the sowing of the crops. Each beast is tethered to its individual stake, the stakes being about 6–8 ft. apart. The position of the stakes is changed after the third night so as to ensure that the whole area to be cultivated gets a thorough dressing of dung. The lowest portion of the island and consequently the first portion to be reached by the rising flood-water is manured and sown first, so that the crop can be harvested before the flood-waters reach it. The high portion of the island is sown last, and in this way a succession of crops is obtained which simplifies the work of harvesting in September. Sowing is finished by the end of June and the cattle then disappear from the picture till after harvest, when they are driven back to the cultivations to eat the dura stalks on the very wet arable land. At this time of the year the land is too wet for tethering outside so the cattle are tied up in the large communal cattle steading associated with every village. The manure from the 'wut', as the communal steading is called, is sometimes used the following spring for manuring early crops of dura, but full use is not made of this supply of dung. The autumn stubble is seldom manured by means of tethering but sometimes, after the land has dried out sufficiently, the village chief or clan leader will order the entire herd to be tethered on his own farm and thus get the benefit of concentrated manuring after harvest.

No doubt the system of mixed farming described above is capable of improvement, especially by the introduction of other crops to the rotation, but it is a system far in advance of anything else to be found amongst the primitive races of the Sudan. It is a system which could with advantage be extended in various modified forms to many of the other cattle-owning tribes in the Sudan to whom the whole idea of mixed farming is either a closed book or looked upon as something to avoid.

Manuring

Although it will be seen from the preceding descriptions of specialized methods of cultivation that manuring of crops is practised, and practised very thoroughly by certain tribes, it must be admitted that manuring throughout the areas of rain cultivation is only seen to a very limited extent. Most tribes manure their tobacco and vegetable crops which they grow near their houses, and the early maturing dura, which usually gets more attention than the main crop, may get a dressing of goat or cattle manure. The Nubas of Kordofan may also manure their 'teras' cultivations. Selected heads from the manured plots are retained for seed. Even this limited amount of manuring, however, is not general, and the applications of farm-yard manure are generally dependent on the appearance of the crop and the energy of the cultivator. Apart from these very

Anti-soil-erosion Measures[1]

Except in the hills and mountains of Kordofan and Darfur provinces very little, in fact practically nothing, has yet been done in the Sudan to arrest the deterioration of good agricultural land by soil erosion. In the north, where the land generally speaking is flat, the need except in town and village perimeters is not so urgent, but in the southern rain areas a flat countryside is the exception and the evil effects of both gully erosion and sheet erosion are clear for all to see. In some cases over-stocking with cattle is the primary reason for the washing away of much good top soil, but in the south the trouble has been brought about mainly by grass fires or by clearing bush on sloping land for cultivation purposes and not taking any measure to prevent erosion through natural causes. In some cases steep hill-sides which should never have been cleared on account of their excessive degree of slope are under cultivation and no adequate measures to prevent soil erosion are possible, but on the remaining areas simple anti-soil-erosion precautions could very easily be undertaken.

The most striking example of anti-soil-erosion precautions which have been undertaken in the past are to be seen in the Nuba Mountains of Kordofan and in the Gebel Marra area of Darfur Province (Fig. 101). Until quite recently the Nuba and Fur were compelled through force of circumstances to live and cultivate on the steep slopes of their hills. In order to make this possible the hill-sides were terraced, each terrace having a facing of stone, and row upon row of these terraces can still be seen scarring the face of most of the hills. The terraces were necessary for two purposes; moisture conservation, and to prevent all the soil on the hill-sides from being washed into the valleys below. Now that the Nuba have descended on to the plains these old terraces are falling into disrepair except in a few places where they are used for growing a small crop of early dura.

To a much lesser extent anti-soil-erosion measures are undertaken in parts of Equatoria Province by piling cleared dura stalks, weeds, branches, &c., in long rows along the top edge of a piece of land cleared for cultivation. These rows of cleanings act as bunds and prevent wash. Strip cultivation is also practised to a limited extent, and in all new areas opened up under the supervision of the Department of Agriculture suitable measures to prevent soil erosion are enforced.

Division of Labour

(*a*) *Family Labour*

The division of labour for agricultural tasks between the various members of the family unit follows a very definite plan which varies with different districts.

In all parts of the country all heavy work in the field such as clearing new land, digging, and sowing is undertaken by the men. Beyond that

[1] This was written prior to the publication in 1944 of the report of the Soil Conservation Committee. In this report there is a general review of the position and a 5-year plan was proposed estimated to cost £E.300,000. The plan was adopted by Government and the funds made available. A Rural Water Supplies and Soil Conservation Board was set up in 1944 to put the plan into execution.—*Editor.*

FIG. 101. Terraced fields on Jebel Marra, Darfur Province, at a height of 8,000 ft. (*photo E. H. Nightingale*).

stage there are great differences throughout the country in the amount of agricultural work undertaken by women. In the northern Provinces the work of the women is confined to assisting with certain of the lighter harvesting operations, although in recent years they have also helped with the cotton picking. In the southern rain-grown areas, however, women take a much more active part in crop production. They probably assist with the sowing and the light cleanings, and they are almost entirely responsible for the complete harvesting of the grain crops. At harvest time they can be seen walking in line from the fields to the villages carrying on their heads great baskets of unthreshed grain. The work of threshing the grain will probably be undertaken by the men, but women do the winnowing. Sometimes certain crops are considered as the women's perquisites. As an example may be cited the simsim crop grown by the Nubas of Kordofan where the proceeds from the sale of any surplus simsim belong to the women.

The actual area which can be cultivated under rain conditions by a normal family without the assistance of outside labour averages about 6 feddans, but if cotton is included in the list of crops grown, it may be necessary to employ two outside helpers at picking time. Instead of growing cotton themselves in cotton areas many cultivators prefer to work as hired labourers in the cotton fields, especially at picking time, and so earn sufficient cash to pay their taxes. Those men only leave home after they have harvested their early grain crops and probably only stay away for a very short time.

(*b*) *Outside Labour*

The main area where outside labour is employed on a large scale is in the Gezira. Here almost every tenant is an employer of labour, especially at picking time, although amongst the West African tenants payment may be made partly in kind. Gash tenancies are also mainly cultivated by hired labour. On the other hand, the proportion of cultivators in the rain belt who employ outside labour as regular practice at most seasons of the year is limited to the larger cotton growers, probably of the merchant type, and also to the large grain growers of Kordofan and the Gedaref district of Kassala Province. The rest of the population cultivate on a family basis, although there may be a certain amount of co-operation at the busy seasons. One of the best examples of good co-operative farming is to be found in the Nuba Mountain district of Kordofan where cultivation is carried out under the 'nafir' system. Under this system a number of men in one village, or perhaps all the men from the smaller villages, bind themselves together into a co-operation called the 'baramka'. The 'baramka' was originally formed as a social and tea drinking society but is now serving a more useful purpose by providing a means for co-operative agricultural work. Members of the 'baramka' go from one individual's cultivation to another and work together until the particular job on hand has been completed on each plot. This is especially the case at sowing time and for cleaning and picking cotton. It is a good system, as a lot of people working together get much more done than would be the case if every individual worked alone. It also relieves the monotony of single toil.

In many places the 'baramka' has very hard-and-fast rules. They appoint from amongst themselves a headman to act as the chief with an assistant to act as his second. These two organize the work, such as deciding where the people will work on any particular day, and all members of the 'baramka' must obey their rulings. If any member has pressing business elsewhere on a day selected for co-operative work, he has to pay a small fine in lieu of work. Failure to pay this fine means dismissal from the society. The fines are used to buy tea and sugar for the members of the society who are working.

(*c*) *Sāqiya Labour*

The division of working labour in 'sāqiya' and the apportionment of costs and profits vary somewhat in different parts of the Sudan. The general principles are well recognized, however, and the division of profits, &c., for areas irrigated by mechanical or other means are often based on current local practice. Three diagrams of the working arrangements for 'sāqiya' are shown below. The first is typical of the Gezira area, and the other two examples show the division in the Dongola area.

(1)

Land		Seed and Imple-ments
Water wheels		Tenants, i.e. Labour
Cattle		Do.
Cattle		Do.
Cattle Food	Seed &c.	Do.

(2)

Land	Cattle and Fodder
Water Wheels	Tenants
Cattle and Fodder	Do.
Do.	Do.
Do.	Do.
Do.	Do.

(3)

Land	Tenants
Land	Do.
Land	Do.
'Samad': Labour	Do.
And Super-vision	Do.
Water Wheels	Do.

In the Gezira 'sāqiya' the owner of the land takes 1/10, the water wheels and their upkeep 1/10. The cattle and their upkeep 2/10+2/30, seed and implements 1/10+1/30, or 4/30 in all. The tenants, i.e. labour for working the scheme, receive 4/10 or 40 per cent. of the gross takings of the 'sāqiya'. The 40 per cent. paid out to tenants in the Gezira irrigated area thus conforms to local custom.

In the first Dongola example the shares are 1/12 each, usually known as a 'khashm'.

Here the landowner takes 1/12, the owner of the water wheels 1/12, the cattle and cattle food 5/12, and the tenants working the scheme 5/12. The tenants' share, in this case, is just over 41 per cent. of the gross profits.

In the last example given the shares are again each 1/12 part: the allocation of shares and of individual responsibilities show some differences.

The labourers: three or four men, take half the crop, but each must provide a bull, must do his share in working on the land, and in making ropes for the 'sāqiya'.

The Samad, or chief labourer, is responsible for all work on the 'sāqiya' and is solely responsible for working the 'sāqiya' at night. He also contributes a bull and receives two shares.

The wheel-owner: hires the wheel for one share, and is responsible for the upkeep of all woodwork, but not of the ropes.

As wheel-owner he does not work on the land, though he may do so if a labourer or 'samad'.

The landowner: rents the land for three shares of the crop. He must produce 2–3 bulls and the boy who drives the 'sāqiya' during the day. As with the wheel-owner, he is not called upon to work on the land.

Actually it is often found that the 'samad', the landowner, and the wheel-owner are one and the same person. If this is so, he recoups himself by taking a half-share of the crop.

Seed is contributed by each member according to his share. The bull strength is 3–4 pairs, contributed as follows:

Labourers . .	3 or 4 bulls
'Samad' . . .	1 or 1 ,,
Landowner . .	2 or 3 ,,
Total . .	6 or 8 ,,

In general it may be said that labour take roughly a half-share and that those who supply the land itself, the irrigation water, and the means whereby it is raised take the other half-share of the total crop.

A 'fifty-fifty' division of crops is a very common one on many of the private pump-schemes in Northern Province, and any divergence from this basis is usually based on the traditional practice for that locality.

CHAPTER XVI

CROPS OF THE SUDAN

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IN allocating space to the crops described, attention has been paid to the amount of information already available in published works rather than to the relative importance in the Sudan of a particular crop. In general, comment is extended only where it is believed to be peculiar to the Sudan and is not already to the hand of those with access to an agricultural library.

Some Crop Statistics

	Estimated area (feddans)	*Estimated production (tons)*	*Exports*	
			Tons	*£E.*
Dura	2,500,000–4,000,000	1,000,000–2,000,000	50,000	250,000
Dukhn	600,000	250,000	2,000	10,000
Sesame	500,000	75,000	15,000	180,000
Oil	..	..	400	13,000
Cake	..	..	5,000	17,000
Total	..	..	20,400	210,000
Cotton	450,000	..	..	..
Seed-cotton	..	190,000	..	..
Lint	..	..	50,000	3,300,000
Seed	..	..	100,000	400,000
Total	..	..	150,000	3,700,000
Less than 100,000 feddans				
Ground-nuts	..	25,000	5,000	40,000
'Lubia'	..	10,000	650	3,000
Less than 50,000 feddans				
Maize	..	25,000	3,000	15,000
Eleusine	..	15,000	..	..
Dates	..	35,000	4,000	35,000
Wheat	..	12,000	100	1,000
Less than 20,000 feddans				
Cowpea	..	10,000	100	1,000
Cucurbits	..	?	..	..
Melon-seed	..	..	6,000	45,000
Cassava	..	?	..	..
Chickpea	..	3,500	2,500	25,000
Less than 10,000 feddans				
Barley	..	3,000	100	1,000
Haricot bean	..	3,000	2,000	22,000
Lupin	..	2,000	550	4,000
Onion	..	5,000	200	2,000
Tick bean	..	2,000	750	6,000
Pigeon pea	..	1,000	..	..
Chilli	..	?	300	10,000

Accurate statistical information is lacking. Export figures may be taken as nearly correct on the assumption that evasion of customs posts was probably of little importance before the war, but figures hitherto published relating to total production are based mainly on taxation returns and are often wide of the mark, and usually omit the provinces of Darfur, Equatoria, and Upper Nile, which contain at least a third of the agricultural population of the country. Most of the figures given here are mere indications unsupported by statistical evidence, and their only value is to give a rough idea of the comparative importance of the principal crops of the Sudan, and a round figure for average exports in the few years preceding the war. That areas seem high compared with yields is due to the absence of land-hunger throughout the productive rain-belt, making yield per feddan less important than yield per unit of effort.

It is doubtful that the total area of any one other cultivated crop exceeds 2,000 or 3,000 feddans. The total area under cultivation appears to lie between 4 and 6 million feddans.

The above list attempts to arrange the crops in a probable order of area sown. They appear to fall into the following order as regards value.

By value of total crop to the producer	£E.	*By value of export*	£E.
Dura	5,000,000	Cotton	3,700,000
Cotton	3,000,000	Dura	250,000
Dukhn	750,000	Sesame	210,000
Sesame	700,000	Melon seed	45,000
Dates	250,000	Ground-nuts	40,000
'Lubia'	200,000	Dates	35,000
Ground-nuts	125,000	Chickpea	25,000
Wheat	100,000	Haricot bean	22,000
Cowpea	80,000	Maize	15,000
Cucurbits	?	Senna	14,000
Maize	75,000	Chilli	10,000
Eleusine	45,000	Dukhn	10,000
Onion	40,000	Tick bean	6,000

The figures in the left-hand column make no claim to being even approximately correct: they are given solely to provide a rough comparison between the crops. The internal value of dura is enhanced by the forage value of the 'qassab', and 'lubia' takes its proper place as a valuable fodder crop. Its seed production is relatively unimportant.

The foregoing lists combine the production of the irrigated areas, the central rain-belt, and the southern Sudan. Northern Province claims practically all the dates and most of the wheat, haricot beans, and tick beans; Blue Nile and Kassala provinces share the Sakel type cotton, and the southern Sudan has all the eleusine and most of the cassava. Equatoria differs markedly from the other provinces and within the province are wide differences in cropping from west to east. A separate order of importance for crops in Equatoria as a whole would be as follows.

First. Dura. This predominates in the clay plains of the cattle-owning areas, but is only one of many crops in the uplands.

Second. Sesame, eleusine, cassava.

Third. *Vigna* and other pulses, sweet potatoes, ground-nuts.
Fourth. Cucurbits, maize, chillies, cotton, dukhn, mango.
Fifth. *Hyptis spicigera* Lam., yams, tobacco, banana, pawpaw.

I. CEREALS

DURA. Great Millet. *Sorghum vulgare* Pers.

'Milium intra hos decem annos ex India in Italium invectum est, nigrum colore, amplum grano, harundinaceum culmo. Adolescit ad pedes altitudine septem, praegrandis culmis, lobas vocant: omnium frugum fertilissimum.' Pliny (A.D. 60–70).

'This millet has longish spikes, composed of small grains resembling hemp seed in colour, in shape somewhat oblong, included in utricles or follicles without awns after the manner of Teasel, and it grows to maturity in the space of three months; then it is cut off and laid on the ground for the space of one month in order that it may be thoroughly dried and cooked through the heat of the sun; at length the spikes are cut off the culms, collected in bundles and carried home, the straw being destined for thatching or furnishing houses. This kind of corn is excellent because when crushed and ground fine it appears perfectly white and bread is ground from it with little labour, since it is very soft, and immediately on grinding it furnishes a dough suitable for loaves. And this kind of corn they always had, even before the advent of the Portuguese. Hist. Ind. Orient. part 6, Cap. 30.' Trans. *Pinax Theatri Botanici*: Caspar Bauhin, 1623.

The grain sorghums are of remote antiquity. At least one wild sorghum, *S. halepense* Pers., is indigenous to both Africa and India, suggesting an origin prior to the land bridges of Pleistocene times. It seems probable that each of these countries evolved its cultivated forms and that there has been subsequent interchange. As dura was apparently unknown in Egypt before the Romans[1] it is likely that the cultivated varieties of Egypt arrived there from India and spread up the Nile to join the local types derived from the Sudan's wild forms. From these origins a wide range of cultivated sorghums has spread to all other tropical countries, where strains have sometimes been improved and then reintroduced to their original homes.

Watt, in his *Commercial Products of India* (1908), suggests that the first mention of the name 'dura' may be Avicenna's reference in the ninth century A.D. to the diet of the people of Zanzibar. Watt also suggests that the word is akin to the Indian name for the grain, *juar*, to which Crooke (*Rural and Agric. Gloss.* 1888) accords derivation from the Sanskrit *yava-parkara* or *akara*.

Being mainly a peasant's crop for home consumption, dura does not figure largely in international trade, and there are no statistics of world production, but it undoubtedly ranks as one of the world's principal cereals. In tropical Africa it predominates, and nowhere more so than in the Sudan, where it provides more food and drink for man and more sustenance for beast than all other cultivated crops together.

It shares only with the date-palm a positive enjoyment of the Sudan's heat. From north to south there are varieties to suit all climates and conditions. Easy to grow, hardy to survive, readily cooked or brewed, and keeping well in store, it is the nutritional backbone of the country.

[1] See p. 26.—*Editor.*

Botanical

In the light of recent original work by S. H. Evelyn, the old name *S. vulgare* (C. H. Persoon, 1805) is reintroduced here for all grain sorghums and the specific nomenclature of later systematists, adopted by Snowden, is here used in the varietal sense, albeit without presumption of authority and solely for the sake of clarity with avoidance of major error. Perhaps inconsistently, the widely used names of *S. halepense* and *S. sudanense* have been retained.

FIG. 102. A nicely weeded, well-grown stand of Dwarf Hegari dura at the Gezira Research Farm, 7 Nov. 1942 (*photo F. Crowther*).

The members found in the Sudan of the large genus *Sorghum* are of four distinct types:

1. *Grain Sorghums*. Dura. (Subsect. *Arundinacea*, series *sativa* Snowden.) No attempt can be made here to describe, botanically or agriculturally, the many individual duras of the Sudan. They number two or three hundred and many are very restricted in distribution. Hybridization confuses botanical identification, and Arabic nomenclature is even more confused, one dura having many different names, and one name being applied to several different duras, according to locality. The few names used here are fairly widely known but are by no means standardized in meaning throughout the Arabic Sudan.

On Snowden's classification the grain sorghums of the Sudan belong to at least eleven different species, but the most important strains are confined to only three of them, here named as varieties, viz.:

S. vulgare Pers. var. *caudatum*. Stapf. This includes most of the hardier, open-headed, and less palatable types, such as Feterita, Wad Akr, Esh

Ahmar, Hajeraj, many of the tall slow-maturing duras of the south, and also the palatable Gassabi.

S. vulgare Pers. var. *durra*. Stapf. These duras are mostly close-headed and of high palatability, such as Safra, Mugud, Himeisi, Hegari, Zinari, Mareig, Wad Fahl, Kurgi, and many of the duras grown along the river in Northern Province under such names as Abu Sab'in and Dibeikri.

S. vulgare Pers. var. *subglabrescens* Schweinf. et Aschers. This includes most of the excellent duras of the Gash and Baraka Deltas, such as

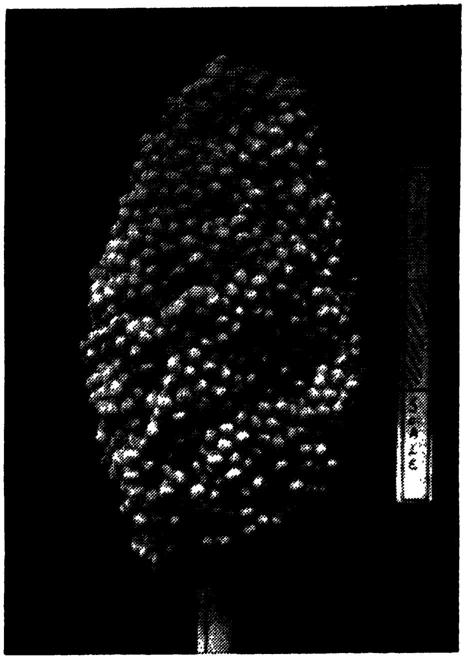

FIG. 103. Close-up view of a head of dura.

Aklamoi, and probably Milo which has recently been reintroduced with success.

Of a similar type, though not primarily a grain-producer, is Ankolib (*S. vulgare* Pers. var. *ankolib* Stapf), which is grown for its sweet stems on a small scale throughout the country. Other sorghums of this type, well known elsewhere, are either absent or of no importance in the Sudan, e.g. Broom Corn, though it has been tried and will grow fairly well.

2. *Sudan Grass Type*. (Subsect. *Arundinacea*, series *spontanea* Snowden.) Most of the grasses of this type go by the Arabic name of 'adar'. Included are the 12-ft. high annual 'adar' grasses of the grass-savanna plains, the troublesome weeds of the rain-dura belt, and the cultivated annual 'garāwi' or Sudan grass (*S. sudanense* Stapf), which, imported into the United States, has there become the premier annual fodder grass. These 'adar' grasses cross freely with cultivated sorghums and are an important cause of deterioration in seed stocks. Many of the so-called 'adar' grasses growing as weeds are hybrids between wild and cultivated sorghums and

often closely resemble the cultivated parents among which they are growing. They can usually be distinguished by the complete and tight enclosure of the grain within the glumes, and the ready shattering of the heads when ripe. The comparatively slender 'adar' that commonly occurs as a weed in the north, notably in the wheat crop, is either identical with Sudan grass or is a very similar variety.

3. *Johnson Grass Type.* (Subsect. *Halepensia* Snowden.) Members of this type are similar in appearance to the annual 'adar', but have a perennial rhizome. It is probable that some of the grass grown here as 'garāwi' is actually nearer to the Johnson grass which has attained such significance as a troublesome weed in the United States and Fiji, where it was introduced as a perennial forage plant, which purpose it still usefully serves.

FIG. 104. A dwarf type of dura.

4. *Other Wild Sorghums.* (Sect. *Para-Sorghum* Snowden.) These are annuals or perennials easily distinguished from the foregoing types by the collarette of hairs on each node. To this type belongs the most important grass in 'harīq' cultivation, 'anis', possibly *S. purpureo-sericeum* Aschers et Schweinf.

Cultivation by Irrigation and Flood

Since the development of communications with the cheap production of the rain-belt, dura-growing on the 'sāqiya' of the north has decreased in favour of cash-crops, and there the crop is now perhaps of greater importance as a source of forage than it is for human food. The thrifty

farmer, anxious to end the dearth of summer, puts in his 'sēfi' or summer crop at the earliest favourable date, which is in May when Lyra reappears as an evening star. The 'dameira' or brown-water crop is sown in September, when water is easier to lift, but this crop is more liable to pests and its importance is overshadowed by the 'selūka' crops sown on banks and islands as the river falls. On 'sāqiya' the seed-rate may be as high as 25 lb. per feddan to allow an ample supply of thinnings and leaf-prunings for the cattle, and to ensure a thin, palatable straw. Naturally

FIG. 105. Dura is the main grain crop of the Sudan. This is a tall type with erect head.

this adversely affects the yield of grain which rarely averages more than one-third of a ton per feddan. Higher yields are common under pump irrigation where it is not necessary to maintain so many live-stock per acre.

On 'sāqiya' the 'sēfi' dura is commonly grown under or near the date-palms which give some protection against scorching winds. Moreover, the palms are often on land nearer the river and therefore easier to water, and this land has normally benefited from the tethering of animals. Dura is a heavy feeder and sometimes receives a top-dressing of organic manure or desert deposit after the second and third waterings. The leaf-pruning at about 6 weeks is said to reduce damage from hot winds, but it is doubtful whether this is beneficial when water-supplies are adequate.

Ploughing for dura is rarely practised in Dongola, though it is becoming increasingly common in Berber and is undoubtedly beneficial, especially where *Striga* is present. A ratoon crop ('butig') is easily obtained with

little extra water, but this practice is discouraged in the interests of stem-borer control.

The 'selūka' crop sown on the falling river has to be sown more thinly or it would die of thirst. Consequently it not infrequently produces higher yields of grain than the irrigated crop, if pests, which are more abundant late in the year, are not severe. Debeikri, Abu Sab'in, Safra, and Mugud types are grown, and fine crops of 9-ft. high Himeisi are obtainable in the basins in a good year, with yields up to a ton per feddan.

FIG. 106. Flowering time in a field of dura (*photo F. Crowther*).

Feterita does not do well along the river north of Khartoum; nor is it popular with riverain folk, but it is often sown by Arabs in the 'atmūr' when the run-off from the desert hills is sufficient to flood patches of clay plain. In the more permeable soils of the 'wadi' or seasonal water-courses large crops of Hemeisi types are often obtained. This remote 'wadi' and 'atmūr' cultivation is so important that Shendi district sometimes achieves a bigger rain-production of dura than Dueim district, though the former is apt to be regarded as a desert district and the latter falls largely within the recognized area of rain cultivation.

Before the Jebel Aulia Dam came into operation up to 10,000 tons of Safra were obtained annually off the mud flats of the White Nile between Kosti and Khartoum. This is a most palatable dura and commands a high price in Omdurman. Its cultivation, with a sowing-stick ('karbol') and sand-covering technique specially adapted to the heavy water-soaked

clay, calls for careful regulation of plant-population in relation to soil-moisture. It is still to be seen downstream of the dam and elsewhere in low-lying places ('lugud') where clay has been subjected to a prolonged flooding under accumulated rain-water. In the aggregate this 'lugud' or 'maya' cultivation is important in the production of superior types of dura in districts that would otherwise be restricted to Feterita types.

The irrigated dura of Blue Nile Province exceeds that of the north, and the type most favoured is a Feterita with fine stems and a tillering and branching habit that ensures a crop even if all the primaries are lost to locusts. It is sown at the end of July or earlier if rain permits, and harvest is completed before cotton picking begins at the end of December. Although the average yield is little more than half a ton per feddan, yields of three times this amount are obtained off good land, particularly if watering is extended to permit maturing of secondaries. The more palatable Gassābi is being grown to an increasing extent, a tendency that should perhaps be discouraged in the interest of security, as its capacity of recovery from pest damage is poor. Dwarf White Milo, recently introduced, shows promise of becoming a staple type in this area.

Cultivation by Rain

In contrast with production of crops from the gravitational concentrations of rain-water mentioned above, rain cultivation proper depends on direct precipitation, though north of about the 16-in. isohyet some concentration and prevention of run-off is obtained on clay soils by low banks often well placed in relation to contours and enclosing on two, three, or four sides, areas ranging from 1 to 10 feddans. Under these conditions a rainfall of 10 in. is sufficient to produce a crop, provided it falls in heavy well-spaced storms within a period of 2 months. In these areas of precarious rainfall cultivation reaches a high standard and cultivators well understand the importance of seed-selection, prompt elimination of weeds, and conservation of moisture by hoeing. Although a short Gassābi is often grown, the most favoured type is a quick-maturing Feterita which possesses to a marked degree a capacity for bringing heads, however small, to fruition, even if deprived of water some time before flowering, in contrast to types which, though equally quick-maturing under favourable conditions, are unable to put up a fight against drought. Crops maturing in 70 days at a height of 3 or 4 ft. are not uncommon, and a crop of this nature would do very well to yield a third of a ton per feddan. Given favourable rains the plant grows taller, tillers and branches, and may exceptionally yield as much as a ton per feddan. Over the whole of the light-rain cultivation belt it is doubtful whether the average yield of the area sown exceeds a fifth of a ton per feddan.

Sowing is invariably done by the 'selūka' and spacing is wide and seeds limited to about four per hole, which at a spacing of a metre each way is equivalent to about 4 lb. of seed per feddan. Thus neither water nor labour is wasted on superfluous plants calling for thinning. Once established, the plant, if freed from weed competition, is remarkably drought resistant for the first 4 weeks, during which it makes little growth. It then grows rapidly and for full success requires not less than three heavy showers at

about 10-day intervals. Dura survives waterlogging better than cotton, 'lubia', or most other crops.

This light-rain cultivation on clays is often more successful on moderately permeable, often salty, land, than it is on more permeable land which under irrigation or heavier rainfall would be superior. For the same reason, dura cultivation by rain on sandy soils does not extend quite so far north as on clay. On sands the deep rooting, slow maturing Mareig Wad Fahl, a handsome swan-necked, large-grained dura, replaces the

FIG. 107. In parts of the Sudan the light rainfall is conserved by impounding behind earth banks and used to grow a crop of dura (*photo at E. Barakat, Aug. 1942, M. C. Hattersley*).

shallow-rooted Feterita. The 14-in. isohyet is about the northern limit, but at this rainfall the crop is precarious as it is liable to drought in the early stages unless it is favoured with frequent showers. It is sown widely spaced by hoe, sowing-stick, or spear, and nomads, unwilling to remain on the job, frequently sow dry, with consequent danger that a light unsupported shower will germinate and kill the seed. Thinning, often neglected, is important to the success of these heavy-headed types of dura.

This light-rain belt, being healthy, is densely populated along the rivers and round well-fields. The people are comparatively sophisticated and industrious and make a major contribution to the country's production. As one goes south the land is generally more fertile, rains are more assured, crop production is much easier; but health deteriorates, population is often sparse, weed growth is heavy, the people are not so money-minded, cultural methods are casual, and standards of performance are often deplorably low. A wider range of duras is grown, mostly taller and

slower in maturing, and attention to seed selection is often neglected, with the result that duras become adapted to the average rainfall and are liable to fail when rains fall short. Provident cultivators, for example the Nuba, grow two or three kinds with different maturation periods and water requirements, thereby greatly increasing their chances of at least partial success. The earliest maturer would normally need to be bird resistant, that is, less palatable or less accessible to birds than seed of the wild grasses maturing at the same time. Such duras are commonly red, rather bitter, and command a lower price than Feterita, which again is lower in price than Gassābi, Mugud, Safra, Mareig, and Himeisi.

'Harīq' cultivation, described on page 292, falls within this 30–16-in. rainbelt, and the varieties most favoured are Feterita, Wad Akr, and Mugud according to soil type and anticipated rainfall. Throughout this zone, whether by 'harīq' or ordinary 'bilad' methods, a good cultivator can under favourable conditions obtain yields equal to those obtained under irrigation farther north, but neglect of crops is common, particularly by nomads, and this, coupled with over-cropping of easily accessible areas, probably reduces the average yield to the neighbourhood of one-third of a ton per feddan. Where simsim will grow it is often alternated with dura to the great advantage of the latter crop.

In Equatoria Province, although dura is the most important single crop as a whole, it is not necessarily so in any one district other than the cattle-owning areas. Strains maturing in 3 months can be sown in localities having an appropriately timed dry spell to hasten maturity. Thus in areas that enjoy double rains there are two possible sowing dates. These types give small heads of inferior red grain. The main crop matures in about 6 months and often yields well, and includes white as well as deeply pigmented varieties. Under certain conditions a variety sown in July may survive the drought and mature in the following July. Its value lies in its time of ripening, for it yields poorly. In general the southern duras are very tall, thus outgrowing the spear-grass, open-headed and therefore less liable to moulds when ripening under humid conditions, and have small deeply coloured inferior grain which is said by the natives to keep better than the large-seeded varieties.

Pests and Diseases

The following list is far from complete, and attempts to give only the major causes of loss in a possible order of importance.

Birds. The semi-migratory Weaver-Bird, *Quelea quelea aethiopica* (Sund), likes to nest in dense bush or tall grass in or near standing water. Its northern limit is about Kosti and Kassala. Nesting colonies may be more than a square mile in extent and upwards of a thousand nests have been counted in one bush of 'kitr' (*Acacia mellifera* Benth.). The flocks on the move, dense as locusts, do extensive damage, but the greatest menace is to grain ripening within daily range of a nesting colony before the fledgelings are ready to move. Netting campaigns have destroyed tons of birds with little apparent impression on the total numbers. Local danger is averted by prompt mechanical destruction of the nests, an arduous communal undertaking that should always be urged on the people and that may

result in the birds abandoning the districts for a number of years. Fear of bird damage often influences cultivators in their choice of seed and site.

The Common Sparrow (*Passer domesticus arboreus* Bp.) is a universal scourge that appears to be increasing, and enforces the substitution of maize for 'sēfi' dura south of Shendi.

The Spanish Sparrow (*Passer hispaniolensis* Temm.) is a variable seasonal immigrant from the north that sometimes strips the crops in Dongola and may range slightly south of Khartoum.

FIG. 108. There's many a slip 'twixt the cup and the lip. In this case four out of five cups are empty having been drained by 'andat' bugs.

These are the three notables among a large number of birds that may regionally cause havoc at seed-time or to the ripening crop.

Locusts. The desert locust (*Schistocerca gregaria* Forsk.) prefers non-graminaceous plants as regards foliage, but makes short work of grain in the milky stage.

The hairy chested or tropical migratory locust (*Locusta migratorioides* Rch. & Frm.) seems to prefer Gramineae, and seasonally does extensive damage in the rain belt and to the irrigated dura south of Khartoum. Its Arabic name 'kabura' reflects its habit of cutting off the young plant at ground level.

Dura Stem-borer (*Sesamia cretica* Led.) is universal, but is most noticeable in the concentrated areas of irrigation and flood, where it may reduce yields to nil if the attack occurs at an early stage of growth. Control in Northern Province is effected by a compulsory dead season, removal of stools, and sunning of 'gassab' to prevent survival of resting larvae.

Grasshoppers and Crickets are always present and often emerge in large numbers, notably at the beginning of the rains, and devastate seedlings and young plants over extensive areas. The use of poisoned bran as for locust hoppers is effective.

Andat (*Agnoscelis versicolor* F.) is a pentatomid bug that at times breeds prolifically and causes severe damage to heads in the milky stage. It is mainly found between latitudes 12° and 14° and is rarely wholly absent from the southern Gezira. With the onset of winter it swarms on trees in torpid clusters which may be destroyed by burning or burying, or be collected and boiled for fat or distilled for tar.

Rats cyclically multiply into plague dimensions and eat seed and seedlings as fast as the cultivator can sow. Notable species are *Arvicanthis testicularis* Sundervall, *Mastomys coucha* A. Smith, and *Tatera robusta* Cretzschmar. Some success has attended the use of poisoned bait, but generally the plague dies down as naturally as it arises.

Striga hermonthica Benth., 'buda' or 'weyl', a root parasite with attractive pink flowers, is almost universal. A change of crop (e.g. to dukhn or simsim) or a shift to fresh land provides a ready answer, but where, as on irrigation schemes or on village rainlands in clay areas of light or medium rainfall, frequently recurring dura crops are required, this weed multiplies rapidly with very serious effects. Punctual hand-picking and burning appears to be the only remedy in these circumstances but is rarely practised. Conditions favourable to rapid early growth of the dura, such as ploughing and manuring, greatly reduce the effect of the parasite, though not necessarily its number.

Smut of various types, commonly *Sphaceolotheca* spp., is of wide occurrence under the Arabic name 'sueid'. The annual loss from this disease throughout the country probably amounts to 5 per cent. of the crop. The heaviest infections are often to be seen in flood cultivation, and low soil temperatures favour the smut spore rather than the dura seed, and this is reflected in the native belief that it is caused by sowing when the land is too wet. Disinfection of seed, which is cheap, easy, and effective, is becoming increasingly practised. No scientific support has been found for the story that smutted seed keeps better in store, though the possibility cannot be ruled out.

Dura Aphis (*Aphis sorgi* Theob.) is called 'asal' (honey) by reason of the excretions of the insects which form a sticky layer over the foliage, causing suffocation in addition to the direct losses by sucking. It is frequently serious in Northern Province and occasionally so in the 20-in. rain belt. No control measures applicable on a large scale have yet been devised.

Sorghum Midge (*Contarinia sorghicola* Coq.) is one of the commonest causes of the condition known as 'masih' or 'masah', partial or total sterility in the ripening heads. Its incidence is associated with rainfall and humidity at and after flowering, and quick-maturing varieties of dura are said to be liable to fail from this cause if sown early south of their usual range.

Tanymecus sparsus Fhs., 'hemeyr', is a small grey beetle that nips off the cotyledons within a few days after germination, notably in the old White Nile Province. Before the operation of the Jebel Aulia Dam it was second only to stem-borer in limiting the success of 'safra' cultivation. It must have cracks to shelter in at midday so does not occur in compact or fine-tilthed soils, and this suggests a method of control. It disappears on arrival of the north wind.

Other pests range from the bacterium of leaf stripe disease to the ravaging elephant which, like the hippopotamus, causes local havoc. The rough peck of the ostrich shatters millions of heads a year in outlying fields, competing with the gentle nibble of the antelope, and the cultivator may also suffer heavy loss from herds of cattle belonging to nomads, to his neighbour's, or to himself.

Uses of Dura

Dura alone does not make good bread, but it is commonly included as one of the constituents of the flour used in making the flat loaves which are rarely seen outside the towns.

'Kisra' is the foundation of the dietary of the bulk of the population. A thin batter is cooked quickly on a wide shallow pan and the resulting thin pancake is folded and mainly eaten by dipping in spiced 'mulah', a meat and vegetable stew whose constituents vary with the prosperity of the time. The best 'kisra' for fresh consumption is made from white or yellow duras, but 'kisra' from Wad Akr or Feterita keeps sweeter and so these varieties are preferred by nomads and workers away from home.

'Asīda' is a dough, prepared as for 'kisra', cooked into a porridge, often with additions. 'Lugma' is a similar but rather inferior preparation.

'Abri' is a thirst-quenching, non-alcoholic drink produced by soaking dried 'kisra' flakes in water. The same name is given to a quite different drink prepared from dates.

'Marīsa' varies from a slightly fermented thin porridge to a creditable dark beer with an alcohol content up to 4 or 5 per cent. In parts of the southern Sudan the men eat dura only in the form of 'marīsa', though the daily dish is a mild preparation compared with the brew carefully prepared with malt and yeast for serious drinking. In this latter form it is widely known and is the only native alcoholic drink of general importance.

'Araki' is a potent spirit, forbidden by law, obtained by distillation of a 'marīsa' of high alcoholic content. The same name is used for the spirit distilled from fermented date liquor.

Whole grain may be eaten boiled ('belila') or roast ('galeia'), but this is not common except that half-ripe heads are often cut, roasted, and eaten as 'ferīk'.

Dura is a good grain for poultry and animals, though its use for this purpose is largely restricted to stock earning money by work or by marketable produce. Bulls and cows make poor use of the grain unless it is kibbled.

When dura is plentiful a family of five may consume it at the rate of 2½ tons per year for food, drink, and live stock, but times of shortage are common and it is doubtful whether a population figure of 7,000,000 represents a dura production of more than somewhere between 1 million and 2 million tons. Under a rationing scheme 1 lb. per head per day is adequate only if there is a number of small heads in the house, or if supplemented by other filling foods; 2 lb. per day is sufficient for a labourer in camp. As this allows nothing for drink or animals, it is consistent with the round figures quoted above.

The export of dura is mainly to feed neighbouring countries, notably

Egypt and Eritrea, when their own crops fall short, but before the war there was a growing export to France, Belgium, Great Britain, and other European countries, largely for feeding poultry and cattle. Dura does not rank high as a source of starch and commercial alcohol.

The use of dura straw ('qassab') for forage is described under 'Forage Crops'. 'Qassab' is also a valuable hut-building and fencing material and is used for fuel.

Storage of Dura

Where rainfall is less than 10 in. the grain in bulk can be stored in open heaps with trifling loss provided the floor is perfectly dry or ventilated. Storage in sacks invites damage by rats and white ants. The sacks rot in the sun, and in the shade or inside a building heavy losses are incurred from the beetle *Rhizopertha dominica* F., the weevil *Sitophilus oryzae* L., the moths *Sitotroga cerealella* Oliv., *Ephestia kuhniella* Zell., and *Corcyra cephelonica* Staint., and secondary pests such as *Tribolium confusum* Duv., all of which, and several others, are collectively called 'sūs' in the vernacular.

In the 20–10-in. rain belt there is a strong tradition of storage founded on hard experience, and most provident cultivators normally have more than a year's supply in hand which they will not sell until the new crop is assured. The main method of storage is in the 'matmura', a circular pit of depth usually equal to diameter and varying in size from ½ ton to 20 tons in capacity. 'Matmura' fields are placed where possible in ground of good run-off of surface water and of close texture, otherwise the sides have to be treated to prevent the cracking that would admit water and air to foster decay. Feterita types may keep well for several years, but the more palatable duras are generally bad keepers.

The 'sueiba' in rain areas looks like a little grass hut on a platform. It is mud-lined, and grain is usually drawn off from a hole at the bottom. In the rainless north the 'sueiba' is a handsome urn-like structure of mud. The 'Umm khashima' is a small 'matmura' for day to day use, often with a narrow trap-door which can be locked.

Heads selected for seed are commonly hung from the roof of the hut, where smoke from the cooking fire doubtless has a preserving effect. Bigger lots of seed can best be kept by treatment with insecticide dusts or in a drum closed with a layer of sand about 3 in. in thickness. Seed from 'matmura' is sometimes of doubtful viability, and the wiser cultivators make germination tests.

Measures and Weights

The ardeb of dura may, according to locality, contain 12, 15, 16, or 20 keilas. The keila is a volumetric measure, and the weight of a keila of dura varies not only with variety and age but also with the conditions under which the crop was brought to maturity and harvested, and with the humidity of the season and the place. Thus old dura may gain 4 per cent. in weight on transfer from Khartoum to Port Sudan. Mugud is one of the lightest, about 26 rotls per keila; Hegari one of the heaviest, about 30 rotls, and Feterita is in between, about 27 or 28 rotls.

DUKHN. Bulrush Millet or Pearl Millet

The cultivated Pennisetums may be considered as all belonging to one species, *P. typhoideum* (Burm.) Stapf and Hubbard, and according to Stapf and Hubbard may be split up into a number of species.

The plant probably originated in tropical Africa, but is now grown in India to an extent of more than 12 million acres. In Africa it replaces dura as the principal cereal on light soils. Thus in the Sudan it is most important in Darfur, Kordofan, the Baraka Delta, and the Latuka area

FIG. 109. A grain-store in the Beni Helba area of Darfur, 1939 (*photo E. H. Nightingale*).

in Equatoria Province, and is useful on sandy islands in the north. It will also grow on heavy soils, though not so well as dura.

The dukhns of the Sudan are of two main types:

1. Relatively short plants with slender stems and numerous lateral heads. The heads are small and the grain almost completely enclosed. The lateral heads continue to form and ripen in succession and harvesting may be spread over several weeks. This type is commonly grown on riverain soils in Northern Province, and, if subsoil water is sufficient, the cumulative yield may exceed a ton per feddan.

2. Relatively tall plants with stout stems and few laterals. The heads are large and the grains are exposed. The heads ripen together (unless abnormal water supply encourages late growth) and can all be harvested at the same time. The native varieties are awnless, but awned varieties from Nigeria have been introduced and are the last to be attacked by birds. This is the type grown by rain and far exceeds the former in extent.

Some of the wild species of Pennisetum are comparable to the annual 'adar' of the genus Sorghum in that they occur commonly as weeds in cultivated dukhn and hybridize freely with the crop.

The cultivation of dukhn closely resembles that of dura and calls for no special comment. It has lower nutritional and water requirements than dura, and its vigorous root system makes it the most suitable crop for the sandhills in the northern limits of rain cultivation, where the

FIG. 110. Bulrush millet is the principal grain crop in the Sudan in the rain areas of Kordofan and Darfur Provinces on the continental or 'qōz' sands.

shallow-rooted duras can survive only on clay, and the deeper-rooted duras find the moisture in the sandhills insufficient. The primaries mature in less than 3 months and need time to dry thoroughly before they will thresh easily.

Dukhn is susceptible to most of the pests listed under 'Dura', and is first favourite with birds. Land repeatedly under dukhn becomes infested with *Striga* which is temporarily reduced by a change to dura, suggesting that the parasite takes time to adapt itself to a change of host.

Dukhn is not favoured as human food in the north unless mixed with other grains. Those from the west who are used to it prefer it to dura, and it is often eaten as 'asīda' (see under 'Dura'). In Darfur there is a technique of extracting from it a kind of corn-flour.

MAIZE. *Zea mays* L.

Maize is a native of America, where most of the world production of 150,000,000 tons per annum is produced. Soon after the discovery of the New World it was introduced to other continents where it has become so naturalized as hardly to be recognizable as an alien. In South Africa it now occupies 65 per cent. of the land under crop and is the main food of the people. Its date of arrival in the Sudan is not known, and it may have arrived through West Africa, where it was introduced by the Portuguese, or through Egypt, where maize cultivation was established in the latter half of the eighteenth century with varieties imported from Syria and India. The Sudanese Arabic names for the plant, 'esh er rif' and 'dura shami', indicate a northern source, but the possibility that it may also have come from the west cannot be ruled out, and Equatoria Province has certainly imported strains from the south.

In the Sudan's maize crop are represented the two sub-species commonly known as Flint and Dent, but they are inextricably mixed. The small cobbed Beladi variety is predominately Flint and the variety Sakatoon is a typical Dent, but most of the local varieties appear to be conglomerations of hybrids. The original 'dura shami' of Egypt was a Flint and the flinty Beladi variety of the Sudan is probably derived from the original introductions, while the Dent types are from better American varieties imported later, either directly or through Egypt.

In general the cultivation of maize resembles that of dura, but it is a heavier and less efficient feeder, so needs fertile soil in good condition. Its rate of water consumption is higher and it is very susceptible to drought. Its need of nutrition and water make thinning particularly important. In the north it is grown as summer, winter, or flood crop, though to a much less extent than dura, except in special areas, e.g. Shendi, where it is popular as a food and on account of its resistance to bird damage. On good soils under irrigation yields of over a ton per feddan are not unusual. Particularly under flood conditions it is often intersown with 'lubia' which does well when the maize is cut out, making use of any residual water. Some of the short varieties mature in about 60 days, others take 120 days or more.

Maize is grown as a rain crop under conditions of assured rainfall in Kordofan, Upper Nile, parts of Equatoria and southern Blue Nile Provinces, though here it is more important as a flood crop. The Sennar Dam Reservoir annually yields about 2,000 tons, important because it ripens in July and August when food and forage stocks are at their lowest. In the Mabaan it is sown early after a year of dearth because of its quick maturity under conditions of humidity and bird prevalence that would not permit quick-maturing duras to succeed. Similarly its use as a winter crop in the north is often to tide over the gap between the dura and wheat crops.

Maize is particularly susceptible to stem-borer which may totally ruin late-sown crops. It is also very liable to aphis attack, but its resistance to bird damage, already mentioned, is a most useful feature. Because it reacts badly to any unfavourable conditions, such as a day or two's

drought, or infertile soil, poor yields of maize are common, but half a ton per feddan is about an average crop. Maize is remarkable for its poor keeping qualities, being readily attacked by all the store pests listed under 'Dura'.

The use of maize for 'kisra' is not general unless dura is scarce. It is commonly ground with other grains, and before full ripening it is popular boiled or roasted. When dura is plentiful cultivators readily sell their maize if there is a demand for export. Because of the inferior quality of its protein, the wide use of maize instead of dura is not encouraged.

ELEUSINE. Finger Millet, *E. coracana* Gaertn.

'Telabun' is an important food crop in the southern Sudan where conditions are too wet to be ideal for the maturation of dura. The wild *E. indica* Gaertn. is the parent form and like dura probably originated both in Africa and in India, where *E. coracana* is extensively grown in the hill districts.

The plant grows to a height of 40 in. with flat stems and digitate inflorescence. It is very tolerant of thin soils and yields heavily on good ones. There are several varieties, maturing in 3–4 months. It is sown broadcast on hoed land, often mixed with dura or sesame or both. Yields of half a ton per feddan are not unusual. The grain has particularly good storage qualities and makes a popular beer.

WHEAT. 'Qamh'. *Triticum vulgare* Host.

As the world's premier cereal, wheat competes with maize in total quantity and far exceeds it in total value, but in the Sudan it is only of local importance. Its origin as a cultivated crop is prehistoric,[1] and the date of its introduction into the Sudan is unknown, but one may presume it to have been soon after the earliest incursion from the north.

Although a little wheat is grown on Jebel Marra and in the Kheiran of northern Kordofan, it is normally regarded as a crop of riverain lands north of Khartoum. As an alternative to the import of wheat flour during the war the irrigated clays of Blue Nile Province added some 20,000 feddans of wheat to their habitual cotton, dura, and 'lubia', with considerable success, and the cultivation and possibly consumption of wheat by the people of this province may remain as a permanent feature.

Old Dongola Province grows about 15,000 feddans of wheat and in prosperous years imports most of the produce off the 5,000 or so feddans grown in old Berber Province, for the residents along the Dongola Reach are, unlike most of the Sudanese, habitual wheat-eaters, preferring the local grain to the cheaper imported flour that meets the need of those with European tastes. Small quantities of wheat are sometimes exported to Egypt ahead of the Egyptian harvest.

Only the Bread Wheat type is grown. The so-called 'Beladi' variety is bearded, and there have been many introductions of bearded and non-bearded kinds with varying success. Some have shown up as potentially

[1] See p. 25. Wheat was also in common use in the Mohenjo-daro civilization dated between 2750 and 3250 B.C. Specimens of this wheat can be seen at the School of Agriculture of Gordon College.—*Editor.*

Fig. 111. Harvesting the wheat crop by hand on Jebel Marra at about 5,000 ft. in May. The crop has lodged from rainstorms (*photo E. H. Nightingale*).

heavier yielders, and some, e.g. the beardless 'Rustom 141', have had such advantages as quick maturity and resistance to rust, but on the whole the 'Beladi' has retained its popularity with most cultivators.

Under irrigation wheat will grow on all except extremely light soils. It is less salt-tolerant than barley but more so than most crops, and fair yields are obtainable off marginal lands that would not do for cotton or dura. On the best alluvial soils it tends to grow too rank, with danger of lodging and rust, and it is better sited back on the 'karū' land away from the shelter of the date palms. It is courting failure to sow in hot weather. The correct sowing date is as soon as possible after the winter wind has arrived, in the hope of maturing the crop before the return of summer, for hot weather during ripening results in shrivelled grain and reduced yields. The farther north one goes the longer is the winter and the greater is the range of dates between which it is safe to sow. Thus wheat sown after November has little hope of success in Khartoum or Blue Nile Provinces, but in Dongola it can be and often is sown as late as January.

A few hundred feddans are sown on land uncovered by the falling river by sowing-stick or 'torea'. In basins, notably that of Kerma, 1,000–3,000 feddans are grown, and here the Egyptian sowing-method of broadcasting on wet mud and covering by a scraper is occasionally seen. A commoner method of sowing in the basins is by ploughing as soon as the land is dry enough. The seed may be broadcast before ploughing, or dropped behind the plough, or broadcast after ploughing and buried with a drag.

The bulk of the wheat crop is grown under controlled irrigation, and here sowing may be done by one of the ploughing methods described above, the land having first been heavily watered. This involves the expense of remaking the irrigation divisions, and the commonest method is to broadcast on unwatered land that may or may not have been hoed or ploughed, and to bury with hoes, rakes, bull-hoes, bushes, or other drags. Broadcasting on land that has been lightly ridged and then re-ridging to raise and bury the seed is a useful sowing method on soils that form a hard crust. If the land is clean, fertile, and in good tilth, Beladi wheat will tiller freely, and with a sowing technique that leaves little seed unburied 100 rotls of seed per feddan is adequate. Double this rate is, however, not uncommon in the grass-infested unploughed water wheel lands of the Shaigia.

Some authorities recommend that wheat be allowed to drought between the first and second waterings, to encourage depth of root development and discourage leafy growth conducive to lodging and favourable to rust. The practice of 'meteig' or leaf-pruning is common if growth is luxuriant. Top-dressings of nitrogenous manure are commonly given during early growth, twice if supplies and energy permit. Water-supplies need careful regulation to avoid shortage at and after flowering and excess during maturation when humidity would favour the spread of rust. The time to maturation varies with soil conditions and variety 'Rustom 141' takes about 95 days, 'Beladi' 120 days, and 'Nizam' 150 days.

When ripe the straw is cut at ground level with the small laborious saw-toothed sickle (Fig. 84*g*) and threshing is effected by the trampling of the family live stock or the bull-drawn sledge with blades on its under surface,

or 'norag', an Egyptian implement bearing some resemblance to a disk harrow. In either case the straw is broken small and under the name of 'tibn' is worth 2–10 P.T. per kantar as a starvation diet for the cattle during the summer months. The local method of winnowing fails to separate the heavier weed seeds, of which a slender 'adar' (*S. sudanense* Stapf.) is the biggest nuisance.

Half a ton per feddan is a fair yield of grain. The amount of straw associated with this amount of grain may range from one to three times the grain weight. Thus yields compare favourably with those of North

FIG. 112. A Fūr woman winnowing wheat at 6,000 ft. on Jebel Marra, May 1938 (*photo E. H. Nightingale*).

America, but as production involves the expense of irrigation and demands a producer price of £E.8 per ton it will remain limited to the needs of local tastes in the face of wheat flour imported at £E.6-odd per ton.

Pests and Diseases

Smut and *bunt* are neither common nor serious.

Stem-borer and *termites* frequently cause extensive local damage, but can hardly be regarded as major pests.

Birds, notably *Passer domesticus arboreus* Bp., sometimes take a heavy share of the ripening crop.

'*Asal*' (*Aphis*) is very damaging in some seasons.

Rust, Ar. 'dhangeil' (*Puccinia graminis* Pers.) is by far the most serious disease of wheat in the Sudan, and may come galloping through at devastating pace, reducing a bumper crop to next to nothing within a month of harvest. It is favoured by warm humid weather and is least likely to attack a carefully watered crop of restrained vegetative growth

in an unsheltered site. The obvious remedy is to grow one of the several resistant strains.

Storage

For store pests see under 'Dura'. Wheat keeps better than maize but not so well as dura. It is unusual for much more than seed requirements to be stored through the year, but to meet war-time needs bulk storage on open floors has proved successful from Khartoum northwards.

BARLEY. 'Sha'ir.' *Hordeum vulgare* L.

The variety grown is *hexastichon*, six-rowed barley. As immemorial and widespread as wheat, barley doubtless came to the Sudan from Egypt and has never assumed much importance. It is essentially a winter crop of the north, like wheat, and is cultivated and harvested in much the same way.

Its main value is that it will succeed on salty or very light soils where other crops would fail. It matures in about 90 days and its water requirement is lower than that of wheat. It competes well with weeds, and under irrigation seems to leave the land in better tilth than it found it. Some 4,000 feddans are grown under irrigation and a rather less area under flood on land that is too salty, too sandy, too weedy, or inadequately watered for wheat.

Given equal conditions (which it rarely gets) it will yield more heavily and more certainly than wheat, being rarely affected by rust. Smut is common but not serious.

Green barley is sometimes used for fattening sheep. The 'tibn' is a better fodder than wheat 'tibn' and contains more leaf. The grain, which is coarse-skinned and of poor quality, is commonly ground with other grains for human consumption but is not popular and is rather a poor man's diet, fetching little more than half the price of wheat. The local barley is a good grain for horses and donkeys in the winter months, but like wheat it has little future in the Sudan by reason of the relatively high costs of production.

RICE. 'Rūzz.' *Oryza sativa* L.

O. punctata Kotschy occurs wild in rain-flooded depressions and, known as 'tibn' or 'tibna', its seeds are harvested in times of shortage. Other wild species are also used in this manner, but *O. sativa*, which ranks with wheat and maize as one of the three greatest cereals of the world, is not indigenous and, though first introduced 40 years ago, has not progressed beyond the experimental stage.

Satisfactory yields have been obtained in trials of varieties introduced from Egypt. Some of the experiments were in connexion with the utilization of the land uncovered by the emptying of the Jebel Aulia reservoir, but it is apparent that rice will not succeed in the northern Sudan without continuous irrigation that makes its production uneconomic. Moreover, the waterlogging propensities of the local soils make them unsuitable for a crop of such heavy water requirement.

Hill rice introduced from the Congo into the wet south-west part of

grew them in his garden. Jumel collected seed from the best variety, experimented, and persuaded Khedive Mohammed Ali to take up cotton cultivation, selling his 'secret' to him for 100,000 francs. Mohammed Ali imported Brazilian cotton seed from 1822 onwards and Sea Island from about 1828, the importation of both types being continued for many years. Modern Egyptian varieties are largely the result of fortuitous hybridization between Jumel's Sudan cotton *G. barbadense* (Watt's *G. vitifolium*) and these two imported types.

Cultivated types of cotton in the Sudan are limited to American Upland (*G. hirsutum* L.) and Sakellarīdes (*G. barbadense* L.) though small amounts of *G. hirsutum* var. *punctatum* (Bilwa) and *G. arboreum* L. (Khilaisi) are grown in Darfur Province for local use.

Cotton Varieties[1]

Two types of cotton are grown commercially in the Sudan—American Upland and Sakellarīdes, commonly called Sakel. The former is cultivated in the Northern Province under irrigation and in Kordofan, Equatoria, and Upper Nile provinces as a rain crop. Sakel is confined to the Gezira area, the White Nile irrigation schemes, and the deltas of the Gash and Baraka. Davie attributes the change from Sakel in the irrigated area south of Khartoum to American Upland in Northern Province to climate acting directly on the plant, but there can be no doubt that the high incidence of pink bollworm in the Khartoum–Atbara zone is also a major factor which the quicker maturing American types are able to circumvent.

The following varieties are in commercial cultivation:

(*a*) *American Upland*

Pump Scheme Strain is a small-bolled, late-maturing, rather monopodial, blackarm-susceptible type. It is very heterogeneous both in vegetative and in lint characters, but its lint is generally graded about $1\frac{1}{16}$ in. and has a ready market. Up till 1930 Pump Scheme Strain was almost the only variety of American cotton grown commercially in the Sudan. It originated as an importation of Nyasaland Upland which itself arose by 'line selection from a mixed crop of long stapled Uplands in which variety Floradora predominated' and which had 'had an opportunity of being contaminated with Sunflower, Griffen and other varieties'. Floradora differed little from its parent variety, Allen's Long Staple.

The faults of Pump Scheme Strain under irrigation are its low ginning out-turn[2] and rather late maturity. The latter character is a definite drawback in certain areas, notably Berber district, owing to pink bollworm. Under rainfall conditions the main faults of Pump Scheme Strain are its low ginning out-turn and its susceptibility to blackarm.

This variety is still grown over most of Kordofan and in Upper Nile Province.

XA129. This variety was bred from a single plant selection in Pump Scheme Strain. It is a sturdy, erect, even type with rather short sympodia,

[1] This should be read in conjunction with the discussion at pp. 567 to 580.—*Editor.*

[2] Ginning out-turn (G.O.T.) is the percentage of lint in seed cotton.

and in Equatoria Province it can be relied on to give 20–5 per cent. more crop than Pump Scheme Strain. Like the parent variety, it is fully susceptible to blackarm.

XA129 is grown in all cotton areas east of the Nile in Equatoria Province.

511D. The 511 series (511, 511A, B, C, and D) arose by continual re-selection from a single plant of Uganda SG85, itself a derivative of Harper's Uganda N17, a type which originated from Nyasaland Upland.

511D is a heavy-yielding type which, under the conditions obtaining in the Equatoria cotton areas west of the Nile, shows an average increase of some 40 per cent. over Pump Scheme Strain and a slightly better quality lint. The 511 series all contain the blackarm resistance gene B_2 and hence are all resistant to the disease. 511D has now replaced Pump Scheme Strain over the whole of Equatoria Province west of the Nile.

513 was bred from an importation of Punjab 'Early Strain'. The type is early flowering and has a shorter boll maturation period than other Sudan varieties, a combination which makes 513 a very early type. Though resistant to blackarm, due to the gene B_2, 513 is not suited to the rain areas of the Sudan, probably largely owing to its lack of drought resistance. The earliness of this strain, however, proved very valuable as a means of combating pink bollworm in Berber district. As a result of the change-over from Webber to 513 on all the Government pumping-stations in this district, the crop was more than doubled.

The lint of 513 fetches a lower price than that of Webber, and the ginning out turn is poor: it averaged only 25·7 per cent. for Berber district in 1938 as compared with 31 per cent. for XA1129 from Dongola area in the same year. The out-turn per gin-hour is also very low: 35 rotls for 513 compared with 50–60 rotls for XA1129.

Wilds No. 11, grown on the Sudan Plantations' Syndicate pumping-station at Zeidab, is an importation direct from America where it was bred by the Coker Pedigree Seed Co. from a cross of Lightning Express × Delta type Webber. Wilds No. 11 is a blackarm-susceptible, big-bolled, long-stapled cotton well suited to irrigation conditions.

Uganda SP84, a derivative of U4/4/2, was imported in bulk from Uganda in 1940 and is being used to replace XA129 on the east bank of the Nile in Equatoria Province. Its advantages are that it is early and that it contains some 60 per cent. of blackarm-resistant plants.

XA1129 was obtained from an off-type plant in Meade. It is an erect, moderately early, small-bolled, blackarm-susceptible type which, under irrigation conditions, proved superior to Pump Scheme Strain by reason of its relative earliness, higher ginning out-turn and better quality lint. XA1129 was used to replace the latter strain in the Dongola area, but its performance was a little disappointing.

Deltapine is being used to replace Pump Scheme Strain in parts of Kordofan. The variety is an importation from the United States; its lint is about the same length as Pump Scheme but is of poor quality. The main value of Deltapine lies in its ginning out-turn which averages about 39 per cent.

(predominantly *Cynodon dactylon* Pers.) that was commonly associated with cotton on the better soils. The constant stream of grass-laden donkeys to the nearest market town testified that the by-product was more profitable than the staple. Many fattening sheep or milk goat habitually 'strayed' into the cotton at night, and an early morning peer over a 'hōsh' wall would often reveal a freshly gathered armful of cotton foliage being enjoyed by the family live stock.

Deltas of the Baraka and Gash: Tokar Delta. X1730A is grown in Tokar (Baraka delta) by means of flood irrigation, but the cotton area is very variable from season to season, being dependent on the quantity and

FIG. 115. Detail of foreground to show the cracking (*photo F. Crowther*).

nature of the flood. In the period 1908–38 the area sown with cotton has ranged from some 21,000 feddans (1908 and 1935) to 116,514 feddans (1920). Not all the area sown in any one season grows 'effective' cotton, and the effective cotton areas ranged, in the same period, from 10,961 feddans (1908) to 70,000 feddans (1920). The variety X1730A is grown in preference to Sakel because the former shows marked resistance to leaf curl under Tokar conditions. Until 1930–1 season this disease had been absent, or negligible, at Tokar, but from then onwards leaf curl became increasingly severe and in 1933–4 some 50 per cent. of the crop was lost on this account. Up to this time Sakel had been grown; in 1935–6 X1530 was substituted as the main crop because of its leaf curl resistance and this was replaced by its congeners X1730 and later X1730A.

Sowing is done following the flood, as soon as the land has dried sufficiently (usually September), but late flushes sometimes wash away areas of young cotton necessitating re-sowing. About 5 seeds per hole are sown and the spacing is irregular, though it approximates to 1 m. × 1 m. Spacing depends very largely on the weed growth and on whether the land was lightly or heavily flooded. Very dirty land or lightly watered

FIG. 116. Weed growth on young cotton at the Gezira Research Farm prior to weeding (*photo F. Crowther*).

FIG. 118. Ridging young cotton in the Gezira (*photo F. Crowther*).

areas may be sown as closely as 25 × 50 cm. Cotton is sown by lifting a slab of the newly deposited silt, which is sterile, to expose the fertile silt below. A hole is made in this by 'selūka' and the seeds thrown in and buried. Thinning to 3 plants per hole is done at 3–4 weeks. On clean, heavily flooded land little cleaning is required and the plant makes vigorous vegetative growth, sometimes attaining a height of 7 ft.; on weedy areas hoeing is often limited to a circle round each plant. Picking starts about mid-December and goes on till mid-May or early June.

The Gash. An 'effective' cotton area of about 30,000 feddans is annually cultivated in the Gash Delta, but, as at Tokar, this is subject to wide

FIG. 119. Ridging cotton on the Gezira Research Farm. A field of dura in the background. The trees mark the site of a canal (*photo F. Crowther*).

variation according to the flood. Approximately half this area is usually sown with X1730A and half with Sakel. As there is little blackarm in the Gash cotton areas they can safely be sown with seed from Barakat Seed Farm in the Gezira. The Gash Delta is thus used not only as a commercial concern but also to propagate seed for the Gezira and to 'filter' it from blackarm.

Cultivation in the Gash is similar to Tokar. Sowing starts behind the flood, as the land dries out, beginning in mid-August and continuing till early September or later according to the flood. Spacing is irregular, but about 1 m. × 1 m. is aimed at with a seed rate of 5–10 seeds per hole. Thinning is also very irregular, though 3 plants per hole is the objective. One or two cleanings are given as early as possible and nothing more is done. Picking starts in early December and goes on till May.

The Gezira. About 200,000 feddans of Sakel and X1730A are annually grown in the Gezira and watered by gravity flow from the Sennar Dam. In the northern half of the Gezira Sakel is grown and in the south

X1730A. Cultivation is by diesel tackle, the land being ploughed and ridged in one process, except when very dirty. Sowing in the north starts about 10 August and is generally completed by the end of the month. In the centre and south sowing begins about 5 days later and carries on into early September. Thinning to 3 plants per hole is advocated 3 weeks from sowing, but there is much variation in the number of plants actually left per hole and the date is usually 1–2 weeks later. Except for a few bull-implements in the northern Gezira, cleaning is all done by hand. Usually three hoeings are given. Picking starts in January and ends by mid-April and the up-rooting of the crop starts on 1 May. Cotton in the Gezira

FIG. 120. Thinning cotton to three plants per hole in the Gezira (*photo F. Crowther*).

usually receives about 15 waterings, though the number may vary from 12 to 18. The usual rotation in the Gezira is: cotton, resting, dura, resting or 'lubia', resting, cotton, resting, resting. On the White Nile schemes vegetative growth is often less vigorous than in the Gezira, but yields may be as good and the proportion of better grade lint is often higher.

(*b*) *Rain Areas*

Kordofan. About 100,000 feddans of American Upland cotton are grown in Nuba Mountains district of Kordofan, where the average rainfall ranges from 25½ inches at Dilling, in the north, to 33 inches at Talodi, in the south. The crop is sown during late June to mid-August, the early sowings generally suffering much less from black arm and drought and producing a far heavier crop. Cultivation is still rather primitive, but a spacing of about 75 × 75 cm. with the crop sown on the flat at 7–10 seeds per hole is the objective. Thinning to 5 plants per hole is recommended as termite damage is usually severe. Picking may start in the southern areas (Talodi) as early as the end of September and, with good rains, may go on till the end of January. In the north, picking starts about the end of October and often goes on well into February.

The average annual production of seed cotton in Kordofan Province in the 5-year period ending 1938–9 has been 107,290 kantars of 315 rotls, about 26,000 lint bales of 400 lb.

Upper Nile. This province, with a rainfall of 30 to 35 inches, grows only about 5,000 feddans of American Upland cotton and produces an average crop of approximately 1,000 lint bales of 400 lb. Cultivation is primitive. The crop is sown in the latter half of July. The spacing is very variable, but in general the cultivators sow much too wide and at too high a seed rate. In thinning, the objective is 3–4 plants per hole, but this is rarely attained in practice. The crop is cleaned by hand hoe or 'malōd' once and

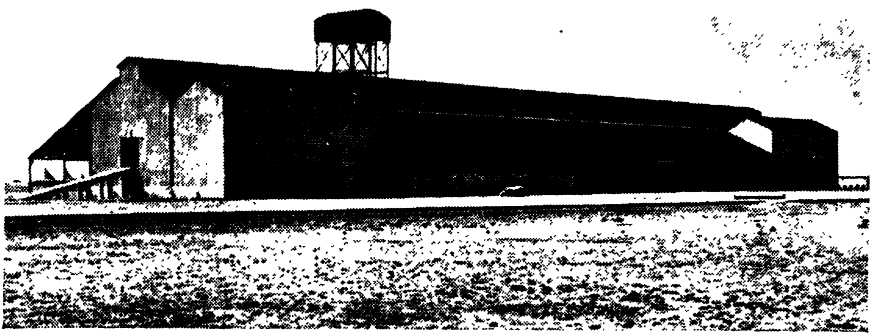

FIG. 121. The Government Ginnery at Port Sudan. Roller ginning of the Gash and of some of the Tokar crop is done at this ginnery.

no other cultivation is done. Picking starts in late October and is carried on till late January. The usual rotation is cotton for 4–5 years, then reversion to bush.

Equatoria. Despite its vast area, Equatoria Province has never produced more than 70,000 kantars (100 rotls) of seed cotton (about 5,500 bales of 400 lb.), and in the 14-year period 1925–6 to 1938–9 the production has twice been less than 13,000 kantars.

In recent years cotton growing in this province has been centred on two ginnery areas—Maridi on the west of the Nile and Torit on the east. Torit area has never shown any great promise, partly because of the lack of interest shown by the local tribes. Cotton growing was discontinued in this area in 1942.

Maridi district and the western half of Equatoria Province (i.e. west of the Nile) probably has a big future as a producer of American Upland cotton, although present production is small.

In western Equatoria land is prepared for cotton by digging with a 'malōd' after burning off rank vegetation and felling or ringing the trees. The usual sowing date is mid-July. The optimum date is probably early June, but the cotton crop would then compete with dura sowing and with

hunting. Both spacing and seed rate are extremely variable and thinning to 2 plants per hole is an ideal which is rarely attained. The crop generally receives one or two hoeings with a 'malōd'. Picking starts in November and goes on till January. Average yields, calculated on large ginnery areas, vary from 250 to 500 rotls per feddan. The rotation is usually cotton for two or three seasons, then dura or other food crops until the soil is exhausted, and then a reversal to bush.

Acreage and Yields. The average areas and yields for the 4-year period 1935–6 to 1938–9 are tabulated below:

District	Area (feddans)	Yield per feddan in kantars (315 rotls)	Total yield in kantars (315 rotls)
(a) *Sakel Areas*			
Gezira	198,960	4·32	859,923
Tokar	29,263	2·27	66,484
Gash	32,934	1·95	64,078
Pumps	12,342	3·62	44,683
Totals	273,499	3·78	1,035,168
(b) *American Areas*			
Irrigated	11,398	3·86	43,955
Kordofan	112,750	0·90	101,825
Upper Nile	7,200	0·58	4,177
Equatoria	20,999	0·79	16,630
Totals	152,347	0·93	166,587

During this period lint production averaged 273,459 bales (400 lb.) of Sakel per year and 37,470 bales American.

Ginneries

There are 26 ginning factories in the Sudan comprising 900 roller gins, 93 saw gins, and 34 presses. Except for the factory at Suakin, all of these are owned either by the Sudan Plantations' Syndicate or by the Government, an ideal arrangement for the maintenance of seed purity.

The Gezira crop is ginned by the Sudan Plantations' Syndicate at Ghorashi, Meringān, Medānī, and Barakāt. Irrigated American cotton is ginned either at Zeidab or Atbara (both roller ginneries) and cotton from the Gash and Tokar is dealt with at Port Sudan. The rain-grown crop of American Upland is all ginned in twelve small saw ginneries sited in the centres of the main areas of production, except that cotton from Upper Nile Province is roller ginned at Sennar.

Disposal of Crop

The Sakel crop (including X1730A) goes mainly to Great Britain and British India. In the 4-year period 1936–9 the former bought 61 per cent. of the Sakel crop and the latter 23 per cent. The American Upland crop was sold mainly to Britain and France (47 per cent and 16 per cent. respectively), whilst British India and Japan each took nearly 10 per cent.

All American Upland cotton and X1730A is normally auctioned at

FIG. 122. Interior of typical roller ginnery in the Sudan. Seed cotton along the wall is fed by hand through the roller gins. The seed drops below the lint, is gathered by trolleys, and taken to the press room. Note the humidifiers above the battery of gins.

FIG. 123. Filling the hydraulic press with cotton lint as the first step in the operation of baling for export.

Port Sudan; the Domains Sakel crop is mostly shipped to Liverpool for sale.

Economic Importance

In cotton production the Sudan compares favourably with the British Empire, in which only India and Uganda produce more. On two occasions in recent years the Sudan crop has exceeded that of Uganda. Cotton represents nearly 65 per cent. of the total value of Sudan exports, and the Gezira Scheme alone contributes some 25 per cent. of the total Government revenue.

The following table shows the cotton exports from the Sudan for the period 1911–39.

Quantity and Value of Cotton Exports from the Sudan, 1911–39

(Five years' averages)

	Lint (400-lb. bales)	*Value £E**	*Total Sudan exports £E*	*Cotton as % of total*
1911–15	16,353†	173,260	1,306,703	13·3
1916–20	16,911	617,867	3,431,230	18·0
1921–5	33,767	861,179	2,791,194	30·9
1926–30	146,256	3,459,136	5,389,298	64·2
1931–5	157,305	1,691,095	3,310,601	51·1
1936–9‡	334,081	3,903,632	6,142,418	63·6

* Including scarto, cotton seed, and, up to 1936, a small amount of unginned cotton.

† In 1911 and 1912 large quantities of seed cotton were exported. These have been converted to lint at 33·3 per cent. ginning out-turn for the purposes of this table.

‡ Four years' average: 1940 omitted because war with Italy affected exports by temporarily closing Port Sudan to normal trade.

In view of the Sudan's position as a cotton producer, a comparison of the above figures with the world crop is instructive. World production for the period 1925–9 averaged approximately 31,982,000 bales of 400 lb., the Sudan crops for 1936–9 averaged just over 1 per cent. of this figure.

Before the war, cotton seed from the remoter ginneries could not stand the cost of transport. Some was used for fuel (at Kadugli tar was distilled as a by-product), some was eaten at will by the local cattle, and much was wasted. The war has stimulated export of seed and expression of oil, and cotton-cake meal, which contains about 5 per cent. of nitrogen, has proved a valuable manure in the absence of sulphate of ammonia.

The home crafts of ginning and spinning and of weaving local cloth (damour) of useful quality was in old days thinly but widely spread throughout the Arab Sudan. Naturally it dwindled with the advent of cheap cotton piece-goods from England and Japan, and for a time it was suppressed by law to avoid the carrying over from year to year of seed which might be infected with diseases and pests, notably pink bollworm. The industry is now encouraged on the understanding that spinners buy

FIG. 124. A typical scene in a Sudan roller ginnery. Note the batteries of roller gins in centre of building, the humidifiers, and the general bustle of activity. A Gezira scene.

FIG. 125. Pressing cotton lint into bales for export at a Nuba Mountain ginnery.

ready ginned lint that is made cheaply available for the purpose of eliminating home ginning with its attendant dangers. For this purpose the coarser cottons are preferred as being easier to spin.

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Pests and Diseases

These are scientifically dealt with elsewhere in this handbook. The following is a brief summary of the most obtrusive in a speculative order of importance.

Blackarm, caused by *Bacterium malvacearum* E. F. Sm., is sometimes called 'huruq' in the vernacular, from the scorched appearance of plants that have suffered a severe attack. Primary (seed-borne) infection, which reduced the yield in the Gezira to 1·36 kantars per feddan in 1930–1, is now controlled by seed disinfection. Secondary infection, from volunteer seedlings and the debris of the previous crop, is combated in the Gezira by the assiduous clean-up after the old crop, but the ultimate solution appears to lie in resistant varieties, and great progress has been made to this end.[1]

Leaf Curl, a virus disease that was mainly responsible for the low yield of 1·92 kantars per feddan in the Gezira in 1932–3, is carried by the white fly (q.v.) and necessitates the labour of pulling out (instead of cutting off) old cotton plants at the end of the season to eliminate ratoon growth from diseased plants as a source of infection. Lambert's X1530, though originally selected largely for its capacity to recover from blackarm, showed a high degree of resistance which persists to some extent in its congeners.[2]

[1] For details see pp. 528–42.—*Editor.*

[2] For details see pp. 542–55.—*Editor.*

Wilt, if the term is applied to all pathological conditions of the root, is responsible for an undefinable but undoubtedly considerable loss of crop every year, and may well be one of the main causes of those drops in yield which for want of a better term are described as 'seasonal fluctuation'.

Pink Bollworm, Platyedra gossypiella Saunders, is widespread and becomes serious in the Gezira towards the end of the season. As already mentioned it is particularly heavy in old Berber Province where it has necessitated early-sowing and quick-maturing varieties. The larvae feed on the ripening seed in the boll, stunting the lint with bad effects on yield and grade. The pest carries over as resting larvae in the seed and is combated by sunning or heating of the seed over which the Government endeavours to maintain complete control, and by elimination of alternative host plants during the dead season.

Sudan Bollworm, Diparopsis castanea Hampson, is frequently very damaging, particularly in Northern Province. It carries over by pupae in the surface soil, and cultivation immediately after the cotton crop has given good results as a control measure.

American Bollworm, Heliothis armigera Hbn., is one of the main causes of bud-shedding of cotton and 'lubia', and *Egyptian Bollworm, Earias insulana* Boisd., also does extensive damage to buds and bolls throughout the country.

Thrips, Hercothrips spp., can seasonally be very damaging, particularly in the Gash, where discouragement by additional irrigation is not possible.

Jassids, notably *Empoasca lybica* de Bergevin, have always been general and now appear to have increased to a serious extent in the Gezira.

Locusts. Schistocerca gregaria Forsk., as hopper or flyer, makes short work of cotton when hungry. *Locusta migratorioides* Rch. and Frm. will leave cotton untouched in the presence of sufficient Gramineae. If past the seedling stage and not yet in flower, cotton can stand a moderate locust attack with little ultimate harm.

Stainer-bugs, Dysdereus spp., are mainly active on rain-grown cotton. The 'tebeldi', or baobab *Adansonia digitata* L., is an important alternative host.

Termites appear to cause loss of stand to some extent in all areas. Thinly distributed throughout the Gezira and sometimes locally severe, the aggregate damage, though difficult to estimate, is considerable. The use of poisons has had some success on an experimental scale.

Cutworm, Laphygma exigua Hb., Arabic 'surfa', sometimes clears a field of seedlings in a night, notably in the north where the delay caused in resowing increases the danger from pink bollworm. Flooding, and brushing the caterpillars into the water, may sometimes be practised with success, but the scourge seems to pass as quickly as it comes.

White Fly, Bemisia gossypiperda M. and L., is chiefly notorious as the vector of leaf curl, but seasonally it is sufficiently numerous to cause vegetative damage by direct action.

Aphis gossipyii Glover, Arabic 'asal', is sometimes serious, but the attack generally lightens with the advent of warmer weather.

Flea Beetle, Podagrica puncticollis Wse., frequently causes severe local damage to young cotton.

Stem-borer, Sphenoptera gossypii Cotes, would cause more damage than it does but for the annual clean-up and burning of cotton stalks in which the larvae rest.

Helopeltis bergrothi Reut. is a bug that has recently come into prominence as a cotton pest in Equatoria Province.

Despite this dismal list, which is by no means exhaustive, cotton is about the hardiest and easiest to grow of the Sudan's crop plants, and escapes may often be found growing lustily as untended weeds.

KAPOK. *Ceiba pentandra* Gaertn.

Sometimes known as the silk cotton tree, this introduction from Asia, though not numerous, has become naturalized and widespread. The floss, which arises not from the seed but from the pod, is too slippery to spin and is used for stuffing cushions and lifebelts, but in the Sudan is not worth the cost of collection.

SISAL. *Agave sisalana* Perrine.

This native of tropical America thrives in the southern Sudan but has attained no importance.

SANN HEMP. 'Til hindi.' *Crotalaria juncea* L.

The genus is well represented in the Sudan, and among the wild species used for making string, ropes, and nets are *intermedia* Kotschy, *retusa* L., *striata* DC., and *cannabina* Schwfth. The last-named is sometimes cultivated by the Bongo.

C. juncea is an introduction that grows well under irrigation, preferring not too heavy a soil. It grows quickly and will serve as a green manure crop, but on northern pump-schemes where local fibres are scarce or of poor quality and difficult to work it has been appreciated as a source of rope. It has been grown only on a small scale and is unlikely to be able to stand the cost of production by irrigation in the face of competition from ropes imported from abroad or from parts of the Sudan where rain-grown fibres are plentiful.

FLAX. 'Kittān.' *Linum usitatissimum* L.[1]

Long known in the Near East and recently of revived prominence in Egypt, flax has been grown in the Sudan only on a small experimental scale. Though growing readily it does not attain a length to compare favourably with flax produced in less severe climates.

INDIGENOUS FIBRES

The Sudan is rich in indigenous fibre-bearing plants which at present are of far greater importance than the four introductions last mentioned. In Bulletin No. 6 of the Department of Economics and Trade (Sudan Government 1938) P. J. Sandison discusses cordage making from Sudan

[1] The word 'kittān' meaning flax and the word 'qutn' meaning cotton are almost certainly derived from the same root meaning a fine fibre. Pliny knew a lot about flax and the art of spinning and weaving fine garments therefrom, but his knowledge of cotton was very fragmentary. Flax was used in Egypt in neolithic and predynastic times. It has recently been reintroduced into the Sudan.—*Editor.*

fibres, and the following list, to which many additions could be made, is largely his.

Grewia mollis Juss. 'basham', Zande 'poigo'.
Corchorus olitorius L. 'mulokhia', Jew's mallow, jute.
Dombeya multiflora Pl. 'gregdan.'
Adansonia digitata L. 'tebeldi', baobab tree.
Sida spp. 'nyada.'
Wissadula rostrata Planch.
Abutilon graveolens. Wight and Arnott.
Hibiscus sabdariffa L. 'kerkade', rozelle hemp.
H. cannabinus L. 'til', Deccan hemp, Bimlipatam jute.
Chrozophora crocchiana Vis. 'dergo', 'ergisi'.
Bauhinia rufescens Lam. 'kulkul.'
B. reticulata D.C. 'kharoub.'
Acacia raddiana Savi. 'Seyal.'
A. orfota Schweinf. 'la'ot.'
A. mellifera Benth. 'kitr.'
Crotalaria spp. already mentioned.
Sesbania spp.
Mucuna pruriens DC.
Vigna unguiculata (L.) Walp. 'lubia helu', cowpea.
Lannea spp. 'umm leyuna.'
Calotropis procera Ait. 'ushar', Dead Sea apple.
Daemia cordata R. Br. 'umm el leben.'
Sanseveria sp. 'za'af el fil', bowstring hemp.
Dracaena ombet Kotschy and Peyr. 'batt', dragon tree.
Phoenix dactylifera L. 'nakhla', date palm.
Borassus aethiopum Mart. 'doleib', near palmyra palm.
Hyphaene thebaica Mart. 'dōm', dōm palm.
Desmostachya cynosuroides Stapf. 'halfa.'

III. OIL SEEDS

SESAME. 'Simsim.' *Sesamum orientale* L.

Some authorities adduce evidence that the Indian Archipelago was the original home of this plant; others consider that there is reason to think that Africa may equally well be one of its native countries. Five other members of the family Pedaliaceae are recorded as growing wild in the Sudan. Some of them have oily seeds and are reputed to be occasionally cultivated on a small scale.

Although world trade in sesame has declined in recent years in favour of other oil seeds, such as ground-nuts and soya, production for home consumption is still of great importance in India and China which together produce over a million tons. In the Sudan the cultivation and internal use of sesame are widespread and appear to have increased rapidly over the last 20 years. Production may now approach 75,000 tons of which four-fifths are used within the country.

The distribution of sesame cultivation in the Sudan is controlled by its inability to withstand either drought or waterlogging, its vigorous tap-root which enables it to exploit the subsoil water in sand-dunes, and its

production by rain at a price that rules out economic production by irrigation. Perhaps as much as 1,500 feddans will be found growing on irrigated lands between Khartoum and Wadi Halfa in small patches for family use, particularly where trading facilities are poor, but this is negligible compared with the output of the rain areas. The biggest producing area is that of the sand-dunes that extend from the White Nile and across Kordofan

FIG. 126. Sesame crop, Equatoria Province (*photo J. F. E. Bloss*).

and Darfur Provinces. Here a rainfall of 15 in. is sufficient, though the seedling stage is always precarious. Much of the clay plain lying across the centre of the Sudan is of too poor permeability for sesame, though it will produce excellent dura, but in certain areas, notably parts of the Fung and Gedaref districts, there are permeable clays which produce very good sesame crops on a rainfall of about 25 in. Provided the soils are well drained, sesame will thrive under heavy rainfall, so it is extensively grown in the Nuba Mountains, the Ingessana, and the hill regions of Equatoria Province.

There are two sub-species of *S. orientale* L.:

(1) *S. o. bicarpellatum*, characterized by a four-loculed fruit and normal numbers of the other flower parts;

(2) *S. o. quadricarpellatum*, with an eight-loculed fruit and sometimes increased numbers of the other flower parts.

Small areas of the latter are cultivated in the southern Fung and along the river Rahad under the names 'umm teiman', 'abu teiman', and 'abu sanduq', but it is not considered to have any advantages over *bicarpellatum* which provides the bulk of the country's crop.

A number of local varieties are known which differ chiefly in period of growth, amount of branching, and seed characters. The period to maturity, which ranges from the 80 days of the quickest Fung type to the 180 days

FIG. 127. Stacking simsim, heads upwards, to dry. Yambio district, Zande tribe (*photo J. F. E. Bloss*).

of the slowest Equatoria strain, provides the main criterion by which varieties are distinguished, and closely associated with this is the amount of branching. Early varieties produce short plants with few or no lateral branches, while late varieties normally produce tall vigorous plants with numerous strong laterals which contribute to uneven ripening of the seed. Conditions of cultivation have tended to a high degree of uniformity in vegetative characters and in time of ripening in any particular variety, but an examination of seed on the threshing-floor will show how inconstant are the seed characters. As regards colour, all the sesame of the Kordofan sandhills is red, white is characteristic of the main crops of Gedaref and the Fung, but there are several minor strains with colour ranging through dark brown nearly to black. There are also differences in the shape of the seed, the roughness of the seed-coat, and in the prominence of the reticulate markings, but oil-content, which is about 50 per cent., does not appear to be associated with these external features. It is believed that

white sesame reverts to red if sown on Kordofan sand. This may presumably be attributed to cross-pollination. The unchallenged dominance of red sesame on the sandhills is probably associated with more vigorous root development in this variety.

On the sandhills dura and dukhn may often be sown before the rains have broken, to take their chance of an adequate starting shower; but sesame, which is not so hardy in the seedling stage, is rarely sown until the land is appropriately moist and perhaps has been cleaned. Holes are made with 'torea' or some type of sowing-stick, up to a yard apart each way, and the seed scattered and buried. Subsequent cleaning, and thinning to not more than 6 plants per hole, are very advantageous but not always practised.

On dry lands broadcasting is the usual method, and the difficulty of subsequent weeding calls for selection of a clean patch of land. Five to ten rotls of seed per feddan are used, and burying is often effected by a light hoeing. Too light rains, too heavy rains, and various pests all militate against the successful establishment of a good stand, and the cultivator mistakenly hopes to counteract the dangers by a liberal seed-rate. He rarely thins; consequently the number of plants is often more than the soil water can support, and probably more crop is lost by reason of excessive plant population than from all other causes together. Much sesame is grown by the 'harīq' method, particularly in small patches in country where tree growth is too heavy for dura.

Sesame is frequently alternated with dura on clays and with dukhn or dura on sands. It is regarded as a recovery crop, and this effect is presumably due to the depth of feeding of the roots at the time when the plant needs most nutrients. Thus the surface layers of soil, used by the dura, are less exhausted by a crop of sesame than they would have been by the weeds that would otherwise have grown there.

When the capsules change from green to yellow, and before they open, the plants are cut below fruit level, tied into small bundles, and stooked. After about a week most of the seed can be obtained when the bundles are inverted and shaken over mats or sacking. Beating with sticks is sometimes necessary to complete the process. The lightness of the seed adds to the difficulties of winnowing and high dirt content is common, notoriously from the Fung. A yield of 600 rotls per feddan is good and the average may be about 400. In most seasons much land originally sown to sesame is resown to dura after the failure of the sesame and in Equatoria Province it is commonly sown mixed with other crops. The keila of sesame weighs about 22 rotls, but the number of keilas to the ardeb varies regionally.

Pests and Diseases

As already remarked, sesame is delicate in the seedling stage, being readily damaged by thirst, by the mechanical action of a heavy storm, by waterlogging on the clays, and by scorch from hot drift sand on the dunes.

Caterpillars, millipedes, and grasshoppers eat the seedlings; ants, rats, and birds remove the seed.

Agnoscelis versicolor F., the 'andat' that attacks dura, also attacks the immature seed capsules of sesame.

FIG. 128. Sesame stacked on drying-frame, Equatoria Province (*photo J. F. E. Bloss*).

FIG. 129. Simsim oil-press 'asara' near Sennar (*photo G. J. Fleming*).

FIG. 130. Tobacco on recent silt on a wadi bank near Jebel Marra. No topping or leaf-pruning is done (*photo E. H. Nightingale*).

Aphanus littoralis, the sesame seed bug, Arabic 'ka'ok', feeds on the capsules in the field and on the seeds in the stooks pending threshing. It attacks dura grain on the threshing-floor in the same way.

Failure of seed formation from the action of a vaguely described fly discourages the growing of sesame in some areas, and appears to be most severe on crops that do not mature early.

Marad ed dam, a bacterial disease due to *Bacterium sesamicola*, is the most prominent single scourge of sesame. In its behaviour, effects, and probably in possible control measures it closely resembles black arm disease of cotton, save that the withered vegetation, as the name implies, is red in colour.

Uses

Sesame seed is a constituent of various dishes. With sugar and flour it makes a popular confection, 'tahniya', and the bulk of the export to Egypt is used in this way.

Internally the oil is used for cooking and anointing. As a food oil and for industrial purposes sesame oil has given ground in recent years to the oils of ground-nuts and soya beans.

In the Sudan there are hundreds of 'asāra', wooden oil-mills operated by camel or ox, and a few mechanical presses. The resulting cake is an excellent and apparently safe feeding stuff for all kinds of live stock. If ground it is comparable to cotton-cake meal as a manure.

The seed keeps fairly well in store but appears to lose some of its oil and may become slightly rancid.

For further information about the sesame crop and its disposal, reference may be made to Bulletin No. 2 of the Department of Economics and Trade (Sudan Government, 1938).

GROUND-NUT. *Arachis hypogaea* L.

'Ful', 'ful sudani', ground-nut, earth-nut, peanut, Manila-nut, monkey-nut, are among the many names for this plant which is believed to be a native of Brazil introduced to Africa by the Portuguese. It is now widespread throughout the tropical areas of the world. India now grows more than 4,000,000 acres and in export is second only to West Africa. World trade in ground-nuts, and in soya to a greater degree, has increased rapidly during this century at the expense of sesame and rape seed.

Occasional small patches of ground-nuts may be found growing under irrigation in the north, doing very well if properly cultivated, but the main production in the Sudan is on sandy or hill soils with a rainfall of 15 in. upwards. The sand-dunes of the White Nile and Kordofan, the Nuba Mountains and Equatoria Province are the main producing areas, but the crop is widespread and will grow on heavy soils if there is neither lime-deficiency nor waterlogging and if the surface is loose enough to allow penetration of the hardened point of the fertilized ovary. Thus there is production for export from Upper Nile Province and southern Fung.

The erect or 'bunch' type is preferred in the wetter parts of Equatoria Province, but the creeping 'runner' type is generally grown elsewhere, and,

though maybe a lower yielder, has the advantages of higher oil content, early maturity, ease of harvesting, and greater immunity from locust damage.

On all except the loosest soils the land must be dug in preparation for the crop. Two or three seeds are thrown in holes spaced at 2–3 ft. Shelled nuts are preferable for sowing, as unshelled seed is liable to rot in the shell, and 20–30 rotls are needed to sow a feddan. Three to five months is the maturation period.

Harvesting must be done promptly lest, if the soil is moist, the new crop should start to germinate. On heavy or binding soils digging is necessary, but on loose soils the plants are pulled up by the roots and stacked to dry for 3 weeks or more, when the fruits can be shaken off. Yields of a ton per feddan have been obtained on experimental plots, but half a ton is a good yield under average conditions and the average is doubtless less than this. The ardeb of 12 keilas of unshelled nuts weighs about 150 rotls.

As with other crops, trials are continually being made with imported varieties, but on the whole it appears that each district has evolved a strain well suited to local conditions, and the so-called 'beladi' strains are well reported on by the trade and have, apparently, the major advantage of immunity to rosette disease which is so serious in East Africa. Apart from squirrels, monkeys, crows, foxes, small boys, and other predators at seed-time, and occasionally root-rot, ground-nuts are singularly free from diseases and pests and the ripening fruit is of course safe from locusts. For this last reason, and also for its value as a restorative crop in the rotation, the growing of ground-nuts is worthy of encouragement.

About three-quarters of the crop is consumed within the country as food, particularly by southern Sudanese and immigrants from the west. The uneven size and brittleness of Sudan nuts have contributed to the poor success of local attempts at machine decortication, and all the export, mainly to Egypt, is undecorticated. Ground-nut oil is among the best of edible oils and the residual cake is highly valued for cattle. Expression of the oil is not practised in the Sudan. The oil content of unshelled nuts is about 30 per cent. Decorticated ground-nut meal, with skimmed milk, has been used as a diet for bucket-fed calves with striking success.

Further information is available from Bulletin No. 3 of the Department of Economics and Trade (Sudan Government 1938), and the epicure who relishes 'ful sudani' soup and peanut butter is referred to *How to Grow the Peanut and 105 Ways of Preparing it for Human Consumption*, being Bulletin No. 31 of the Experimental Station, Tuskegee Institute, Alabama.

Melon Seeds

By far the most important is that of *Citrullus vulgaris* Schrad., the Water Melon, Arabic 'battīkh'. Though cultivated along the river, this Mayfair delicacy grows freely as a weed on sandy soils of light rainfall. In Kordofan and Darfur Provinces, where the bulk of the seed export comes from, it receives a certain amount of care and protection from cattle, and is perhaps best described as a desired weed of cultivation, for it appreciates the comparative cleanness of land that is or has been under cultivation. The cultivated strains are sweet, but the wild ones range from sweet to

bitter and vary in size and appearance. They are a valuable alternative to drinking-water for man and beast in desert areas.

There is a brisk trade in 'battīkh' for fruit near centres of population, but the main economic importance of the crop lies in the export to Egypt of the seed, which contains a limpid oil. Salted and cooked, the seeds are sometimes eaten as an appetizer. In the Sudan in times of famine they are ground into flour.

Citrullus colocynthis L., 'handal', is a wild plant widely distributed in the northern Sudan. Its pulp is very bitter, containing about 0·6 per cent. of the drug colocynthin. The fruit is distilled for a tar used in dressing water-skins. The seed contains up to 17 per cent. of an edible oil. The slightly larger 'gurum', semi-cultivated in the north for its seed, may belong to this species, and *Cucumis melo* L. var. *agrestis* is another wild cucurbit with a seed rich in oil. Known as 'senat', the seeds are sometimes roasted with salt and used as a masticatory.

CASTOR. 'Khirwa.' *Ricinus communis* L.

Though at least one variety is indigenous to Africa, it is probable that the plants seen growing on river banks and elsewhere are escapes from commercial introductions. It grows well by irrigation or rain on open soils, and trials with introduced strains have given satisfactory yields far in excess of those obtained from the vegetatively vigorous wild or semi-wild types. At present its commercial exploitation in the Sudan is on a trifling scale.

Hyptis spicigera Lam. Bongo 'kindi', is found wild in the Fung and in Equatoria Province where it is increasingly cultivated, often mixed with dura and eleusine. The seeds are eaten, like those of sesame, as an oily paste. They contain about 29 per cent. of an oil comparable in drying qualities to that of linseed, and this suggests commercial possibilities.

SAFFLOWER. 'Gurtum', 'usfar'. *Carthamus tinctorius* L.

The flowers yield an orange dye (used in ancient Egypt) and the seeds a clear esculent oil. For these purposes the plant is cultivated on a small scale throughout the Sudan.

SOYA BEAN. *Glycine max.* (L.) Merr.

This native of the Far East has been tried continuously in the Sudan since the beginning of the century, with seed and soil inoculants from various parts of the world. For many years it appeared that the fifty-seven values ascribed to this plant by its advocates could best be attained by crops better suited to the climate, but recent trials at Shendi, with July sowing, have given encouraging yields of beans and fodder. It will have to do well to compare with *Sesamum*, *Arachis*, and *Hyptis* for oil, with *Vigna*, *Phaseolus*, *Arachis*, *Cicer*, *Cajanus*, and *Vicia* as pulses, and with *Dolichos* as leguminous forage.

OIL PALM. *Elaeis guineensis* Jacq.

This handsome introduction[1] from West Africa is well suited to parts of Equatoria Province where its development on an economic scale has

[1] Its natural range extends eastwards to the Bwamba forests of Uganda.—*Editor*.

recently begun. As in addition to oil it provides food, drink, and building material, it may locally come to assume the importance enjoyed by the date palm in the north.

LINSEED. *Linum usitatissimum* L.

This has grown well in small trials as an irrigated winter crop in the north, but this is probably a re-introduction because flax was produced in Egypt in Neolithic and Predynastic times.

FIG. 131. Moru girl extracting oil from 'lulu' nuts (fruit of *Butyrospermum Parkii* var. *niloticum*) (*photo J. F. E. Bloss*).

SUNFLOWER. 'Ein esh shems.' *Helianthus annuus* L.

This has done very well in trials and has been used as green forage and included in silage. The readiness with which it droughts is a nuisance on irrigation schemes and rules it out for rain cultivation. Yields of seed, and oil content, compare favourably with those obtained in other countries.

SHEA NUT. 'Lulu.' *Butyrospermum parkii* var. *niloticum* Kotschy.

This large and useful timber tree is indigenous to Equatoria Province. The kernels of the nuts yield about 50 per cent. of a stearine fat known commercially as shea butter. It is locally used for food, anointing, and illumination.

IV. PULSE CROPS

For ground-nuts and soya bean see under 'III. Oil Seeds'.
For 'lubia 'afin' see under 'V. Forage Crops'.

COWPEA. 'Lubia helu', &c. *Vigna unguiculata* (L.) Walp.

The Sudan forms of the plant known as catjang in India show great diversity in appearance and habits of growth. Some strains are highly pest-resistant and will grow on over-watered land too heavy for other crops. It is rare to find irrigated or river-flood cultivation without a small patch or a few rows of *Vigna*, and this hardy plant is a common constituent of rain cultivation, particularly that tilled by westerners. It is important in the Nuba Mountains and is the main pulse crop of Equatoria Province. Under irrigation it can be sown at any time of the year.

The names 'lubia helu', 'hanatir', and 'warrag' are usually given to the small type with dark green foliage, short erect pods, and small smooth seeds usually brownish in colour.

'Lubia beida', 'lubia tayiba', or 'lubia kordofani' usually denotes a larger spreading plant with long pendant pods and large wrinkled white seeds.

Strains with red, black, mottled, and piebald seeds occur, and vegetative characteristics vary widely.

The leaves may be eaten as salad or included in 'mulah', and leaf-pruning appears to stimulate seed-production. The immature pods of the smaller types are at least as good as the local French bean and are a valuable summer vegetable. The seed is mainly eaten as 'belila' (boiled) and is also roasted. Export is trifling, practically the whole of the crop being consumed within the country, most of it by the growers.

Vigna vexillata Benth. is another useful member of the genus. It grows wild on a rainfall of 25 in. upwards and has a swollen root that appears to be superior in flavour and nutrients to the sweet potato. In Gedaref and the Fung it is called 'babun'.

CHICKPEA. 'Hummos.' *Cicer arietinum* L.

'Hummos' is the name generally used by the trade, but northern growers commonly call it 'kebkabeik'. The plant is widely grown in Mediterranean and Eastern countries and is the common or Bengal gram of India. It is probably not indigenous to the Sudan, but a very early introduction. Yield and price are not high enough to make chickpea a profitable crop under irrigation. It is characteristically a crop of basins and river-banks, and is usually sown on land that has been flooded too long or is too heavy to produce a crop of dura. Thus its sowing date is commonly October and November.

As with *Vigna*, its cultivation calls for no special comment. Sowing is usually done by 'selūka' though the plough may be used in basins as described under 'Wheat'. Seed-rate varies with the prospective soil-water supply, from 2 to 6 keilas, as the plant is small. If not accelerated by drought, the maturation period is 4½ to 5 months. Immature pods are

picked for use as a green vegetable, but the main harvest is done with the small-toothed sickle, and the whole plant is threshed.

The local variety is much smaller in seed than the 'fransawi' variety grown in Syria, which has succeeded in preliminary trials. Yields are generally low, 2 ardebs of about 325 rotls being quite good. It does not appear to be a very popular food in the Sudan except in Ramadan, and the bulk of the crop is exported to Egypt as quickly as possible, for it is very susceptible to store pests.

HARICOT BEAN. 'Fasulia.' *Phaseolus vulgaris* L.

Though several species of *Phaseolus* are native to the Sudan, *P. vulgaris* is an early introduction to Africa from the New World. A strain having coloured beans is grown on a negligible scale in the extreme south, but the white haricot is essentially a northern crop and is found mainly in Khartoum Province and old Berber Province, rather more on 'selūka' land than under irrigation.

The common variety, with white- or cream-coloured flowers, has largely lost its climbing habit and is a fairly compact plant, so should not be spaced more than 40 × 40 cm. between holes, with 2 or 3 plants per hole. This requires about 2 keilas of seed. August sowings are often attempted, to catch the early market for green pods, but insect pests are active during the rains and there is much flower-shedding in hot weather, so October is the safest month for sowing. Green pods are ready for picking from 7 weeks, and the removal of the pods as they mature so prolongs vegetative growth that healthy plants will yield 2 tons per feddan of green pods in a month and go on to produce an ardeb of dry beans. If all the fruits are left on the plant, growth soon ceases, and 3 ardebs is a fair yield. Several hand pickings are necessary to avoid loss by shattering, which is incurred when, for lack of labour, the crop has to be cut and threshed in bulk.

A black-seeded variety, 'fasulia zarga', of more erect habit and with purple flowers, gives a more tender pod for green use and is grown on a small scale near towns, but there is no demand for its dry beans (though they taste like the white ones) except for seed. The bulk of the white bean crop is exported. It stores well.

'Fasulia', like most leguminous crops, is very liable to root diseases and to termite damage. It is very seriously affected by a virus disease that crinkles the foliage and deters bud formation. For these reasons it often does better on clean river-flooded land than under controlled irrigation.

Phaseolus mungo L., black gram, is popular in Equatoria Province as an alternative to *Vigna*. Trials have indicated that this plant may have possibilities as an earlier sown and quicker maturing leguminous forage than *Dolichos* in the Gezira Scheme. A variety with small green seeds is occasionally found cultivated along the rivers, and is known in Northern Province as 'lubia tamassi'.

Phaseolus lunatus L., the Lima or butter bean, 'fasulia arīda', occurs wild and is cultivated in areas of adequate rainfall. The green pods are harmless, but the ripe seed contains a glucoside that gives rise to prussic acid. The poisonous property is destroyed by boiling.

LUPIN. 'Termis.' *Lupinus termis* Forsk.

This white-flowered lupin, though not so attractive as the blue lupin of the Lebanon, is a handsome plant that is grown north of Khartoum on flooded lands too hard or salty for other crops. In basins it precedes even barley as a reclamation crop, and here it may be sown early in the wet mud by Egyptian methods. Otherwise the 'selūka' is used, with a spacing of a foot each way and a seed-rate of about 3 keilas per feddan. It takes about 3½ months to mature and yields 3–4 ardebs per feddan. It enjoys comparative immunity from pests, but chafer grubs sometimes attack the roots and caterpillars the flower buds.

The seed, which stores indefinitely, is bitter and mildly poisonous until boiled and strained when it is very nutritious and relished as an item of local diet.

TICK BEAN. 'Ful masri.' *Vicia faba* L.

This introduction from temperate climes is a popular foodstuff in the Sudan and would doubtless be more widely grown but for its climatic requirements—it likes a long, cold winter—its susceptibility to disease and its marked preference for the best soils. Small areas are grown by 'selūka' on the falling river, even south of Khartoum, but it is mainly an irrigated winter crop of old Dongola Province.

It makes no attempt at growing on land that is weed-infested or in bad condition. Seed-rate is about 3 keilas per feddan. The crop matures in 4 months and, though bad crops are common, on the best soils healthy plants may obtain a height of 6 ft., and yields of over a ton per feddan have been recorded. Half a ton would normally be considered very satisfactory. Harvesting and threshing methods are similar to those employed for wheat.

It is susceptible to root diseases, termites, caterpillars (*Laphygma* sp.), a disease of the nature of green ear, rust (*Uromyces fabae* (Pers.) de Bary), mildew (*Leveillula taurica* (Lev.) Arn. and *Erysiphe polygoni* D. C.), and 'asal' (*Aphis*). A severe attack of the last-named may reduce the crop to nothing, but it is bacterial diseases of the nature of chocolate spot that are mainly responsible for restricting the fragrant bean-fields to the northern districts of Northern Province.

The garden 'broad bean' variety has great difficulty in setting seed in this climate, and is rarely successful.

PIGEON-PEA. 'Ads sudani.' *Cajanus cajan* (L.) Millsp.

Alternatively known as 'lubia adassi', this is a native of Africa and it appears that India owes its important 'dal' crop to this continent. Except occasionally on islands it is unusual to see a pure stand of this plant, but it is extensively grown on margins and as wind-breaks on irrigated and flood lands, and is found in small quantities throughout the heavier rain areas, so the total production must be considerable. It is very hardy and pest-free and on permeable soils can go without water for a long time. As a wind-break it is sometimes grown as a perennial and occasionally behaves as such on islands, as it does on rain-lands in parts of West Africa.

The commonest strain in the Sudan has light brown or reddish seeds, but strains with white and mottled seeds are occasionally found in the Fung and in Equatoria Province. The yellow flowers and the green pods are frequently streaked with purple. The plant ranges in height from 4 to 8 feet and appears to take 5 or 6 months to maturation of the earliest pods. There is, however, scope for investigation on the effect of short days on time to flowering, and on the introduction of quicker maturing strains.

Successive picking of the pods may continue for several weeks, with total yields of dry seed ranging from half a ton to a ton per feddan. The seed, which is all consumed within the country, does not fetch a good price. A high proportion of the vegetation is too woody to be relished by animals, and these two factors, combined with the labour of hand-picking the small pods and the length of time to ripening, doubtless militate against an increase in area of this productive and nutritious crop. Cajanus was given a protracted trial at the Gezira Research Farm for its rotational value as a deep rooter and a nitrogen restorer, with negative results.

CHICKLING VETCH. 'Gilban.' *Lathyrus sativus* L.

This attractive plant with purple-blue flowers is cultivated in the north of Northern Province on a small scale in the winter. Both foliage and seeds are normally used for animals. Its requirements of irrigation water are light relative to the yield, which, after about 4 months' growth, may be half a ton of seed and about the same weight of dry forage. The seed is often eaten by the poorer classes.

FIELD PEA. 'Basilla.' *Pisum sativum* L.

This is also an irrigated winter crop of the north, easily discouraged by unseasonable heat. The old-established variety known as 'beladi' has a purplish flower and a small grey seed. The white-flowered 'afrangi', not quite so hardy, has a larger, generally green, seed. Superior varieties can be grown with care in the garden.

Peas are a favourite subject for *Laphygma* and other caterpillars, and are susceptible to root diseases, but if all goes well and the weather is favourable, heavy yields are obtained. The area grown rarely exceeds a few hundred feddans and depends on the export market to Egypt.

BAMBARRA GROUNDNUT. 'Ful abu ngawi.' *Voandzeia subterranea* Thou.

This shares with *Arachis* the peculiarity of burying its pods to ripen, but it is much inferior as a food. It occurs in the Nuba Mountains and in Equatoria. The hard-shelled pod contains one seed as hard and round as a marble, which is boiled or ground for food.

LENTIL. 'Ads masri.' *Lens esculenta* Moench.

This plant is delicate in the Sudan, which is really too hot for it. Small areas are grown in the winter in Dongola and Halfa in response to the temptation of high price, but failure is more frequent than success.

SWORD BEAN. 'Lubia el fil.' *Canavalia ensiformis* DC.

This is widespread as a wild plant in the heavier rain areas and is made use of, green and ripe, for food. Also known as the Jack Bean, it is cultivated to a small extent. It grows readily under irrigation in the north and can be of use as a summer vegetable. Its yield of forage compares unfavourably with that of *Dolichos* and is palatable only when dry. It was given a thorough trial as a rotation crop at the Gezira Research Farm, but had little but its hardiness to commend it.

OTHER BEANS.

MUCUNA spp. exist in the wild state, and the introduced Velvet Bean has been grown with moderate success in trials. So also has the Cluster Bean, *Cyamopsis psoraliodes* DC., but neither commends itself as a rival to established pulse crops. Horse Gram, *Dolichos biflorus* L., occurs wild in the south, but does not show much vigour when grown under irrigation farther north.

V. FORAGE CROPS

DURA STRAW. 'Qassab.' *Sorghum vulgare* Pers.

Apart from the vast areas of natural grazing, the vegetation of dura sustains more animals in the Sudan than any other plant. Naturally it is most important in the desert north, on irrigation schemes and in areas of light rainfall, and decreases in importance with the increase in wild vegetation. By far the greater part of this forage consists of dry straw from which the ripe heads have been harvested, so it is coarse, woody, and of low feeding-value. The need for an edible straw influences the cultivator towards fine-stemmed varieties and, under irrigation, to a heavier seed-rate than is compatible with optimum grain-yield. Forage requirements undoubtedly account for the continued popularity of the fine-stemmed 'Abu Kalleiga' type of Feterita in the Gezira Scheme. 'Kalleiga' means bundle and is a common unit of forage, and the implication of the name is that a single plant tillers and branches so freely as to produce a bundle on its own. The yield of 'qassab' is of course very variable with variety and conditions affecting vegetative growth, but 1,000 rotls to the small ardeb of grain is a rough guide, with a tendency to a higher ratio on irrigated land. The 'kalleiga' ('warataba' in the north) tends to get smaller if demand is keen, and may weigh anything between 4 and 10 rotls, and the price varies from 10 P.T. per hundred at harvest to ten times this figure in the summer. 'Qassab' is commonly stooked or stacked and protected by a thorn fence until required for sale or home consumption, but there is much waste, and the 'sāqiya' cattle of the north could be saved much of their present starvation if 'qassab' were more carefully conserved and not so freely used for fuel in the winter.

Thinnings and leaf-prunings are given to hand-fed stock, but green 'qassab' is not commonly grown solely for forage except in the vicinity of towns where prices are high and where it is particularly prized for animals in milk. With a seed-rate of 40 rotls per feddan heavy cuts can be obtained in a few weeks in hot weather. Summer sowings grow quickest and largely

escape the stem-borer. On very fertile land and with heavy irrigation, cuts of 30 tons green weight per feddan have been obtained with 8-ft. high 'Abu saba'in' near Khartoum, with the second and third cuts totalling another 25 tons. Such yields are of course exceptional, and 10 tons followed by 5 tons is about an average crop.

Such 'qạssab', cut at flowering, makes excellent hay, and the growing of dura specially for hay is a common and profitable practice in Khartoum Province. It is all too usual, however, to see the feeding value lowered by over-exposure to the sun and by cutting delayed until the formation of grain which is invariably eaten by sparrows.

MAIZE and DUKHN 'qassab', after harvest, are very inferior to that of dura in palatability and digestibility. Cut young for greenstuff or hay they are as good as green dura and are grown for this purpose in the few localities where forage prices are high. Green maize has a good reputation for milk production and would doubtless be grown more often but for its liability to stem-borer. Thirty-five tons green weight per feddan has been obtained under favourable conditions, including thick sowing, fertile soil, and frequent irrigation. Dukhn will beat dura only in the cold weather and is less susceptible to stem-borer. It is probably the best crop for a quick yield in the winter and will give two or three cuts. Green weights of winter dukhn are about half those of summer dura.

DOLICHOS LABLAB L. 'Lubia', 'lubia 'afin'.

This plant is more widely known by its botanical and Arabic (?Persian) names than by its various English names, of which hyacinth bean and bonavista bean are two of the commonest. De Candolle refers the word 'lubia' to the Greek 'lobos', applicable to the prominent pods. Wild in India and widely cultivated throughout Asia as a garden crop, it is probably not indigenous to Africa but came up the Nile long ago. Elsewhere it appears to be cultivated mainly for its beans; in the northern Sudan it is grown mainly for forage and has here attained greater importance, relative to other crops, than anywhere else in the world.

'Lubia' will grow on any adequately flooded land, and on any odd corner of the steepest river-bank it will contribute its succulent foliage, sweet-scented flowers, and nutritious beans. The 'afin' appellation is hardly attributable to the flowers, though sickly in abundance. It may refer to the mildly offensive odour given off by the foliage when bruised, but is probably ascribable to the unpalatability of the cooked beans, unless specially treated, compared with those of the cowpea, 'lubia helu'.

Nearly half the flooded river land in Northern Province is annually cropped with 'lubia', either alone or with dura or maize. On 'sāqiya', similar interplanting is common, and on pumping-schemes it is the restorative crop of the rotation. On mixed alluvial soils the recuperative effects of a good crop of 'lubia' are well recognized. On the irrigated clays of Blue Nile Province, where with cotton, dura, and much resting land, 'lubia' completes the rotation, its residual effect is less marked, but if well grown it certainly leaves the land no worse than it found it. 'Lubia 'afin' is not much grown in the rain areas, liking neither flood nor drought.

There are two flower colours, white and purple, which will breed true in isolation, though most parcels of seed are mixed. White preponderates in the Gezira Scheme, purple is as common as white in the north. The purple is said to be more vigorous and the beans of the white strain more palatable, but these differences, if real, are slight and in other respects the two strains are similar. A white-flowered variety introduced by Massey and known as Shambat Indian Bean gives a heavier final yield of foliage but is somewhat slower in growth in the early stages, and its beans are less palatable. Sudan 'lubia' (unlike some imported strains) is sensitive to length of day. Experiment has shown that plants grown under 11 hours' daylight per day will flower in 56 days, under 12 hours' daylight in 83 days, while under 13 hours' daylight there is no sign of flower formation. (The experiment was discontinued after 127 days.) Naturally, vegetative growth is much more vigorous in the absence of flower formation. At the latitude of Khartoum (15° 36′ N.) the time between sunrise and sunset is 12 hours 1 minute on 1 October, and during the latter half of December is 11 hours 13 minutes. The cultivator can make use of these facts to obtain maximum vegetative growth or quickest seed production, as he requires.

'Lubia' will grow all the year round, but it thrives best in hot weather. If the plant is healthy, which it usually is on northern soils, one to three heavy cuts can be obtained off early sowings followed in the winter by a yield of beans little inferior to that off an uncut October-sown crop. 'Lubia' is often badly neglected. Under these conditions it will give a crop of sorts, but it responds more markedly than cotton or dura to good treatment, which it rarely gets. A good seed-bed, freedom from early weed-growth, and careful watering throughout will multiply the crop five-fold. In the north it often has to contend with hard unploughed grass-ridden soil. On heavy land it is very susceptible to the ill effects of over-watering and there is much poor 'lubia' to be seen on the irrigation schemes of Blue Nile Province. In addition to the loss in crop, its residual value as a legume is lost and weeds are increased instead of smothered. Given a fair start 'lubia' can be an excellent smother crop. It is sown in holes by 'selūka' or 'torea', and seed-rate varies with expectation of growth. Thus winter sowings would be closer. Summer or 'dameira' sowings on good land will give a full cover if spaced 2 ft. each way, but spacing of 1 ft. or even less are rightly used on untilled 'sāqiya' lands. Thus the seed-rate ranges from 1 to 4 keilas per feddan. Particularly in old Dongola Province it is customary for hand-picking of leaves to begin as soon as the plant is well established and to continue as long as the crop is allowed to stand, which may be until April. This leaf-pruning is said to be beneficial to bean production, but the reason for it is to provide a steady income of greenstuff, mainly for hand-fed stock but also used boiled as a vegetable. The practice naturally cancels the value of 'lubia' as a smother-crop, but probably attains the maximum yield of foliage and beans. It is no uncommon sight to see donkeys put to graze in grass-infested *Dolichos* as they do not like the 'lubia' and eat only the grass. This does not work with ruminants, which prefer the 'lubia'.

Ten tons of greenstuff per feddan is a very good yield for a first cut in

Northern Province, and half this amount would be considered good on Blue Nile schemes. Frequently cattle are allowed to graze the standing crop and yields are not measured. 'Lubia' is excellent for both milk and meat. Early morning grazing is attended by danger from hoven. The making of 'lubia' hay for storage is a common and commendable practice, but it needs care against excessive loss of leaf, best avoided by baling while the hay is still green, and letting it dry in the bale.

The beans can be eaten green as a vegetable but are mostly left to ripen for hand-picking and threshing. If beans have been the main objective, which is unusual, the yield may be as high as 4 ardebs per feddan, but as the bean harvest is normally subordinated to forage requirements, 1 or 2 ardebs is more usual. 'Lubia' beans are an important supplement to the local dietary. They are fully susceptible to store pests. There is a small export to Egypt, and 'kashrengeig' is the name often used for the beans by the trade.

The most serious disease of 'lubia' is *Xanthomonas phaseoli* (E. F. M.) Dowson, comparable in its effects to black arm on cotton and 'marad ed dam' on sesame. This disease flourishes during the rains and in Blue Nile Province forces the sowing date back to September which is later than the optimum. Root affections are common, particularly on heavy soils, often resulting in death after the first cut. Termites and chafer grubs sometimes cause local havoc, and American bollworm is very fond of the flower buds, which is immaterial to the cultivator aiming at forage. 'Lubia' is a favourite host of white fly, the vector of leaf curl, so grown immediately after cotton 'lubia' not only hides ratoons but ensures contact with the vector.

'Lubia' is the only annual leguminous forage crop of any standing in the Sudan. Properly treated it is a very good one, and in trials has consistently defeated all challengers, whether from the home stable or from overseas. Its full value to man, beast, and soil is difficult to assess.

LUCERNE ALFALFA. 'Bersīm hegazi.' *Medicago sativa* L.

To Egyptians the word 'bersīm' denotes the annual clover that is the mainstay of their rotation and annual husbandry and one of the pleasanter features of the country-side. In the Sudan, unless specifically stated otherwise, 'bersīm' means the perennial lucerne which is forbidden over most of Egypt lest it carry cotton pests over the dead season.

Native to the eastern Mediterranean and western Asia, lucerne has developed a wide range of varieties and has spread across the warm-temperate world. The success of what is probably an Arabian variety in the Sudan refutes the statement that it will not thrive in the tropics. A little is grown in England, 2–3 million acres in France and other European countries, 12 million acres by rain and irrigation in the United States, and over 20 million acres in the Argentine where it occupies nearly 40 per cent. of the arable land under crop. It enjoys heat and its vigorous tap-root enables it to resist drought. It cannot stand soil acidity, excessive salts or waterlogging, and dislikes high humidity, so Sennar is about its southern limit in the Sudan and it is much happier on the permeable soils of the north than it is on the clays of Blue Nile Province. In the Sudan it

grows only under irrigation and only a few hundred feddans are grown, mainly on Government farms or on private pumps near towns.

Because of the delicacy of the seedlings and the plant's dislike of waterlogging and binding soils it is best on heavy land to be satisfied with half a crop and to sow on high flattened ridges. On kinder soils the seed is broadcast on the flat and raked in. A fine seed-bed is essential, and no good farmer would put lucerne on land that is not free from perennial weeds, notably 'nagīl', *Cynodon dactylon* Pers. Seed costs about 8 P.T. a rotl, so for economy, and because the crop is to stay for several years, every effort should be made to ensure good germination and establishment of an even stand. Thus soaking the seed before sowing enables unburied seeds to strike and eliminates unevenness from floating. Very gentle admission of irrigation water prevents the bare patches resulting from scour. Seed-rate ranges between 12–20 rotls on ridges and 30–50 rotls on the flat according to tilth and other conditions affecting establishment of the plant. From Khartoum northwards the beginning of winter is the time to sow. South of Khartoum the early rains (end June) is an alternative date.

After 7 weeks or more a first cut of 2 tons per feddan of rather watery greenstuff is obtained, followed 4 or 5 weeks later by a cut of 3 tons or so. The poor return for this period is very serious to the water wheel cultivator who has to keep his bulls fed, and the difficulty may be surmounted by sowing a nurse crop, such as barley (80 rotls per feddan) or dukhn (25 rotls per feddan). The latter will give a cut of 3 or 4 tons after about a month (cut high to avoid damage to the lucerne) and doubles the yield of greenstuff at the first and second cuts of the lucerne. It then fades out, leaving the lucerne no worse and perhaps slightly better than it would have been without its nurse. Topping, i.e. cutting the lucerne half-way up at the time of the first cut, is a good strengthening practice, particularly if the stand is on the thin side.

Once the plant is established the time to cut lucerne is just before full flowering. In Northern Province the intervals vary from 20 days in the hottest weather to 45 days in exceptionally cold weather, an average of 12 cuts a year. As 5 or 6 tons per cut is a common yield off good second-year lucerne, the crop's performance in the Sudan is the envy of farmers from Britain or the United States, where a total of 6 tons a year is considered excellent. Indifferent crops are common, however, and average yields are less than half the figures quoted. 'Asal' (*Aphis*), cutworm (*Laphygma*), and, in the Blue Nile Province, blister beetles may make for a thin plant from the start, letting in the grass, which gets on top during the rains. The general cause of deterioration of the plant is deterioration of the soil from its continued frequent irrigation. Thus on clay soils the crop rarely lasts more than 3 years, whereas on open loams in the north it has been known to flourish for 10 years.

Seasonal attacks of cutworm, notably in May and September, relieve the farmer of a cut or two. *Rhizoctonia* and other root diseases are sometimes serious and hasten the end.

As setting of seed weakens the plant it is usually taken only off a field due for breaking, so yields are low, 500 rotls for a first pick and 300 rotls

for a second pick, per feddan, being good. The summer is the time to obtain pest-free healthy seed. It is usually hand-picked, threshed, and cleaned at piece-rates of up to 2 P.T. per rotl, so offers a profitable wind-up to the crop. Purchasers of seed on the open market need to watch for contamination with cheap seeds very similar in appearance, such as those of clover and various crucifers.

This nutritious forage is in keen demand for horses, milk cows, and other stock, and the price of lucerne hay ('derīs') at Khartoum sometimes rises from £E.4 per ton when forage is plentiful to £E.18 in times of scarcity.

EGYPTIAN CLOVER. 'Bersīm masri.' *Trifolium alexandrinum* L.

This backbone of agricultural practice in Egypt is of no importance in the Sudan. If grown, it needs the same cultivation as lucerne, with double the seed-rate. If successful, its first two cuts are earlier and heavier than those of lucerne, but it soon fades out when the weather gets hot.

SUDAN GRASS. 'Garāwi.' *Sorghum sudanense* Stapf.

Curiously, in its cultivated form this grass is now regarded as an introduction from Egypt. From their perennial habit it is probable that some of the strains are nearer to Johnson Grass, *S. halepense* Pers. 'garāwi' is very little grown in the Sudan, probably because in the north the Abu Sab'īn type of forage dura is hard to beat, and south of Khartoum, where 'garāwi' appears to grow more quickly than dura in the summer, there is little summer irrigation water and the forage problem is less acute. In the winter it is slower than dukhn. It makes an excellent green forage or hay, will do well on land too salty for dura, and the perennial types show less deterioration than lucerne on very heavy soils. It is less affected by stem-borer than dura, and probably should be grown more extensively, particularly in Khartoum and Blue Nile Provinces. Yields of greenstuff are generally lower than those off forage dura or dukhn, but cuts are more frequent.

TEFF GRASS, *Eragrostis tef* Trotter, and many other introduced and indigenous forage plants have been tried, but none compares favourably with the established crops described.

There is a wealth of good fodder grasses produced annually in the rain areas of the Sudan. Most of it is wasted by fire or cannot be exploited because of its distance from water-supplies. Mechanized hay-making on a big scale, with high-pressure baling, in rain areas adjacent to the railway, appears to offer the logical solution to the problem of feeding the live stock necessary to the northern towns and of relieving their overgrazed perimeters of one of the main causes of soil erosion. The haying of natural grasses is at present practised only by the Government on a small scale in the rain areas, and by sedentaries along the river in the north.

VI. MISCELLANEOUS CROPS

No attempt is made to make this section complete. Most European annuals can be grown in the northern Sudan in the winter with appropriate precautions, and introductions from other tropical countries are continually being tried in the central and southern Sudan. The following selection of indigenous and introduced crop plants is arranged in the order: drinks, drugs, spices, vegetables, and oddments.

COFFEE. 'Bun.' *Coffea arabica* L., *C. robusta* Lindon.[1]

Parts of Equatoria are well suited to the growing of robusta coffee. Indigenous species grow on the Acholi Hills and the Boma Plateau and cultivated varieties were introduced at least 20 years ago. On experimental farms continued progress is being made in establishing cultural practice and nurseries, but expansion on a commercial scale is slow, largely because the low prices are unattractive to cultivators.

Except on the Boma Plateau the acid soils of Equatoria Province are not suitable to the growing of Arabian coffee.

TEA. 'Shai.' *Camellia sinensis* (L.) Kuntze.

Only those uplands of Equatoria Province with acidic soils and well distributed rainfall are possible tea-growing areas, and tea growing on these lands is still in the experimental stage.

ROZELLE. 'Kerkade.' *Hibiscus sabdariffa* L.

For production of the rozelle hemp of commerce a variety (*altissima*) has been developed that grows with little branching to a height of 12 ft. or more, but the wild and cultivated 'kerkade' of the Sudan is a small bushy plant rarely exceeding a height of 5 ft. It yields a good fibre and the seeds are used medicinally, but the chief reason for its widespread cultivation in small quantities by irrigation and rain is the red fleshy calix which is a valuable antiscorbutic generally taken in the form of a refreshing drink. It also makes a good jam and jelly. A white form is known. Export of the dried calices may amount to 100 tons, at a price of £E.20 to £E.50 per ton.

QUININE. 'Kina.' *Cinchona* spp. L.

An experimental plantation in Equatoria Province did not succeed but suitable areas appear to exist in the Imatong Mountains.

TOBACCO. 'Tombak', 'Qamsha'. *Nicotiana rustica* L., *N. tabacum* L.

By legislation cultivation is restricted to those areas that grew tobacco at the time of the trade agreements with Egypt. A little is grown along the northern reaches of Northern Province, but the main areas of production are Darfur Province, the Nuba Mountains, the southern Fung, and Equatoria Province. 'Qamsha' or 'dukhan' is a coarse-growing plant used mainly for smoking; 'tombak' is a smaller plant and is more used for chewing.

[1] By some Botanists *C. robusta* is regarded as a variety of *C. canephora* Pierre. —*Editor.*

variety can be grown in the coldest weather, but quickly passes the approved crisp stage.

JEW'S MALLOW. 'Melūkhiya.' *Corchorus olitorius* L.

This common weed, a form of the jute plant, is perhaps the most used in cooking ('mulah') of all green native vegetables. 'Khudra' is another name for it. Under cultivation it is best established in the hot weather, and its small seed calls for a fine seed-bed. It yields a first cut after 20 to 30 days and several subsequent cuts at 15-day intervals, growing to a height of about a foot.

LADY'S FINGERS. 'Bamia', 'weika'. *Hibiscus esculentus* L.

The 'okra' of the West Indies, now widely grown throughout the tropics, primarily for its fruit and incidentally for its fibre, is considered by De Candolle to be of African origin. Several wild forms occur in the Sudan throughout the rain belt, varying in height from 3 to 7 ft. and in pod shape from thin horns 6 in. long to ovoids 1 in. in diameter. Sometimes called 'weika el afrit', the wild plant is very irregular in occurrence from season to season; an area may show a nearly pure stand of 'bamia' one year and nothing but grass the next. It is a common weed of rain cultivation, and superior strains are occasionally cultivated by rain and extensively so wherever there is irrigation. As it is used even more in the dry than in the green state, it beats 'melūkhiya' for pride of place as the most important vegetable in Sudanese dietary.

It thrives best in hot weather, and early summer sowings, for which the seed-rate is 4 rotls per feddan, will start to yield after 90 days, giving 240 baskets of green pods per month for 3 or 4 months. A basketful sells for 2–5 P.T. The total yield per feddan may amount to 6 tons green weight. For drying the pods are picked a little coarser, and should be sliced and dried in the shade, the sun being admitted only if moulds appear. The dry weight is about 12 per cent. of the green weight.

August, September, and October sowings sometimes do well, but fruit production is delayed if the weather turns cold. Winter sowings are made, to meet town demands for green pods, but often do badly. Not only does the plant grow and fruit less freely in the cold weather, its many pests are more active. Most of the insect pests of cotton attack 'bamia' (hence there is an enforced dead season for the crop in cotton growing districts) and it suffers badly from mildews (*Sphaerotheca fuliginea* (Schl.) Poll. and *Leveillula taurica* (Lév.) Arn.) and from leaf curl (*Gossypium* virus). Valuable work has been done towards producing more vigorous, heavier-yielding, disease-resistant strains.[1]

SWEET POTATO. 'Bambei.'[2] *Ipomoea batatas* (L.) Lam.

Brown and Massey (*Flora of the Sudan*, 1929) record forty wild species of *Ipomoea*. Some of these, growing in seasonal swamps, have edible shoots

[1] For a note on Knight's Momtaza variety see p. 584—*Editor*.

[2] A corruption of 'Bombay', thus indicating an introduction to the northern Sudan via India. This does not rule out the possibility of an introduction to the southern Sudan, where it is called 'Batatas', overland from West Africa. This plant found its way from America to China before America was discovered. —*Editor*.

and tuberous roots which are used for food, but *I. batatas* is believed to be of New World origin. Like most root crops it does not appeal to the northern Sudanese palate and the little grown under irrigation is mainly for the European demand of the towns. Its length of time to maturity, the deterioration of the land during irrigation of the crop, the hard labour of extracting the deep tuber from the compacted soil, the uncertainty of the market and great difficulty of storage all militate against its expansion in the north. Under rain cultivation in Equatoria Province, however, it has become a staple item of diet in some areas, is expanding, and is encouraged for its immunity from locust damage.

It can be propagated by cuttings or tubers, the former being usual. Under irrigation, cuttings are planted at the beginning of winter and the crop matures in 5 to 6 months. On well-manured open soils yields of 10 tons per feddan of tubers and a similar weight of rather poor quality green forage can be obtained. A recently introduced pink variety is sweeter than the older established white strain, which generally gives a bigger yield.

In Equatoria Province planting is done at the beginning of July. Humic soils of open texture are preferred, and yields of 1 to 2 tons per feddan are obtained after about 4 months. There are at least five varieties differing in vegetative and tuber characteristics. The tubers of one variety are said to keep in the ground for four years. Sweet potatoes now occupy several thousand feddans and have dispelled the fear of famine in the areas of their establishment.

CASSAVA. 'Bafra.' *Manihot utilissima* Pohl.

The manioc or tapioca plant, like the sweet potato, is believed to be an early introduction to Africa from S. America. It has long been cultivated in the south of Equatoria Province and is known in the southern Fung and elsewhere in regions of adequate rainfall. It can survive a fairly long spell between wet seasons and persists untended to provide a safe underground reservoir of nutritious food. For this reason and for its large yield, its extension to all suitable areas is to be encouraged. Its popularity as a staple food has advanced since the introduction, by the late Dr. J. G. Myers, of the South American technique for removing the bitter element. The following description is from one of Dr. Myers's reports.

The bitter variety of cassava is by far the more nutritious. The bitterness is due to a cyanogenetic glucoside which in the sweet variety, used as a vegetable, is mostly concentrated in the skin. The local technique for preparing bitter cassava involves soaking the roots in water for 3 days to eliminate the poison. This eliminates also a great part of the food value and results in an evil-smelling product. The South American Indian technique is briefly as follows:

(1) Roots washed and peeled.
(2) Grated on home-made grater—a perforated side of a petrol tin nailed on a board.
(3) Pulp placed in the 'snake', a long extensible basket-work strainer made locally after a South American model.
(4) Pulp left straining for at least 4 hours and the effluent poisonous juice caught in a vessel below.

(5) The still moist pulp from the strainer is cooked into thin cakes on a flat cooking plate as used for 'kisra'. The cooking takes only a few minutes. Flour is obtained by spreading the moist pulp to dry in the sun, and then sifting.

(6) The juice is allowed to stand for a day and is then decanted from a layer of very fine white tapioca starch which has come down from suspension.

FIG. 132. Azande woman preparing cassava. The root is soaked, beaten up, and dried on the rocks. The product is partly decomposed and smelly (*photo J. F. E. Bloss*).

(7) The decanted juice is boiled gently for a day to the consistency of a thick honey, and a dark brown colour. This is cassareep, the basis of West Indian pepper-pot and many famous sauces.

The introduction of this improved method of preparing cassava will not only afford a useful addition to the native diet,[1] but should also enable cassava to take its place among the more promising money crops. There should be a market both for the flour and for the starch deposited from the juice.

Cassava is easily propagated by cuttings and will start to yield within a year. Strains resistant to mosaic have been introduced.

YAM. *Dioscorea* spp.

Eight indigenous species are recorded, more than one being edible. The variety increasingly grown in Equatoria Province as an anti-famine crop is probably a cultivated form of *D. alata* L. Its cultivation is widespread,

[1] Leaves of cassava are used as a vegetable and constitute an important source of vitamin C.—*Editor.*

though nowhere on a large scale. A nutritious flour is made from the dry tubers.

COCO-YAM. 'Qulqas.' *Colocasia antiquorum* Schott.

This introduction from Asia is popular in Egypt but is rarely seen under irrigation in the Sudan as it takes a long time to mature and prefers a high humidity. Along with the similar aroid *Xanthosoma sagittifolium* Schott. it is grown on a small scale in Equatoria. The tubers are very palatable and of high feeding-value.

EGG-PLANT. 'Bedingan.' *Solanum melongena* L.

The bringal is a popular vegetable widely grown on a small scale under irrigation. Seedlings are planted out in the cool weather of winter or the rains, and the plant will continue to bear during hot weather if its stem is not attacked by borers, chafer-grubs, or termites. Its worst pest is a scale insect that can with difficulty be kept in check by spraying but generally involves the uprooting and burning of the crop.

TOMATO. 'Banadora', 'temātem'. *Lycopersicum esculentum* Mill.

This native of tropical America must have arrived here a long time ago and doubtless from more than one direction, for it is now universally popular and grown where rain permits and wherever there are means of irrigation, including water carried by hand from the well. It also grows well on good 'selūka' lands uncovered by the Blue and main Niles.

The hardiest and most disease resistant is the small cherry type, and this is the one chiefly found under rain conditions. The so-called 'baladi' type, and the most universal, has badly shaped and deeply creased fruits. It is very prone to the devastating virus disease to which some of the superior introductions show a questionable degree of resistance.

In the north the best crop is generally obtained by sowing in boxes in October and planting out in November, but if the land is free and the weather not too hot there is much to be said for sowing direct and singling later. The growth and yield of the crop vary greatly from season to season. A yield of 60 tons per feddan was picked one year at Shambat off good varieties properly staked and well manured, but less than a third of this figure was obtained the following year with similar treatment. Yields of over 30 tons are recorded from Shendi Experimental Farm. Manuring is important not only for its effect on yield but to promote leaf growth sufficient to prevent sun-scorch. Staking is rarely practised by native growers and far less fruit is picked than is lost by rats, water and earth-damage, and scorch. A yield of 7 tons per acre is as much as can normally be expected.

The virus appears to be least active in the winter, so there is often a glut and no price for winter-grown tomatoes, and market gardeners are always trying to establish an early or late crop. The excess fruit is sliced and dried and finds a ready sale as 'salsa', which is one of the minor exports of Darfur. Commercial canning is just beginning on a small scale and will call for more work on varieties with good flavour and high solid content, and hardiness to lengthen the season of production.

PUMPKINS and MARROWS. 'Qara' and 'qara kosa'. *Cucurbita* spp.

Many and varied are the varieties of these vegetables grown under irrigation or on land uncovered by the receding river. Some introduced strains are very sweet and excellent fruits. Generally speaking, the more tasty varieties are the more susceptible to pests, notably melon bug and mildew.

MELONS and CUCUMBERS. *Cucumis* spp.

Sweet melons and cantaloups ('shammam') are among the main fruits of the country, and types of cucumber (agur, kheyar, tibish) range from the

FIG. 133. Cutting up water-melons on the Maaba Qōz in summer of 1936 as water substitute for cattle. In a good melon year cattle can summer on the Qōz for several months after other sources of water have vanished (*photo E. H. Nightingale*).

short prickly indigenous strains to the long smooth-skinned introduction. In the winter, trade in these cucurbits is of considerable local importance. Much care and skill are sometimes shown in cultivation, but mortality from pests is very high, and clean low-lying islands often give better results than the irrigated main lands. These islands are often very sandy, and the plants require hand watering until established. In Dongola one sees little mud wind-breaks to keep off the drift sand. Near Shambat holes are excavated in the sand and filled with soil to promote contact with the water-table.

WATER MELON. 'Beteikh.' *Citrullus vulgaris* Schrad.

The sweeter forms take a place in cultivation and local trade along with the above. They are much hardier and more easily grown, need no manure, and are often planted casually along the sides of canals or on any

bit of waste ground, and given an occasional watering to go on with. The main value of this plant is discussed under 'Oil Seeds'.

WILD CUCURBITS.

At least forty species occur wild in the Sudan, some with several varieties. Those useful to man, such as the loofah, *Luffa cylindrica* (Lour) Roem (Arabic 'lif'), and *Lagenaria vulgaris* Seringe which yields gourds of various useful shapes, are often planted, sometimes to grow over the

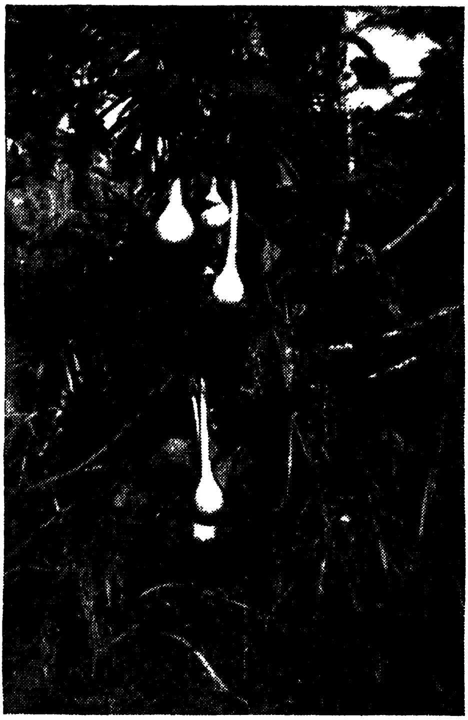

FIG. 134. The bottle gourd *Lagenaria vulgaris* Ser. provides useful containers and is much used in the Sudan. This is the pipes and spoons variety.

grass hut of the cultivator. One or two species have small, beautiful scarlet or orange fruits that hang from their supporting thorn-bush like gaudy lights. Some have medicinal properties, and many provide food for man or beast, like the thirst-quenching ovoid 'hameid', beloved of ostriches and camels. These are characteristically quick-growing and mostly die at the end of the rains, but some persist if watered and are worth growing in the garden, notably the loofah, which, if sown in the rains, is the quickest plant for covering a screen, with handsome dark foliage and a bright crop of large yellow flowers every morning.

SUGAR-CANE. 'Qassab sukar.' *Saccharum officinarum* L.

In 1909 some 70 feddans of cane for sugar production were grown at

Berber with fair success. Since then trials have been intermittent and on a small scale. Sugar-cane growing for jaggery production for local consumption has been included in the Zande experiment and sugar-cane trials in various parts of the Sudan continue.

Soft cane for chewing is grown on a small scale in the south and under irrigation in the north in occasional small patches near the towns. Because imported sugar is comparatively cheap in the northern Sudan, and because sugar-cane requires a lot of water the year round, its growing in this area is discouraged by law so as to make the land available for crops of greater value to the community.

CAMPHOR. 'Rihan.' *Ocimum kilimandscharicum* Gurke.

There are several indigenous species, including basil, *O. basilicum* L., to which the common weed of the Gezira area belongs. Investigation has shown that the local plants are not worth commercial exploitation and a more productive species was introduced from Kenya and grown on a small scale by the Government during the war. The plant is easy to grow under irrigation and will tolerate indifferent clay soils. The oil and the crystalline camphor are extracted by a simple steam distillation, and 1 ton of these products can be obtained from 20 feddans of a good crop.

HENNA (Arabic). *Lawsonia alba* Lam.

This introduction used to be a profitable minor crop for export and still has some commercial value, though now mainly grown as a quick and fragrant hedge. It is readily propagated by cuttings. The young leaves are picked, dried, ground, and made into a paste used in the Sudan to dye the nails, hands, and feet. Seventy to ninety tons is a usual export, worth about £E.2,000.

INDIGO. 'Nila.' *Indigofera* spp. L.

This genus is very well represented in the Sudan, including some of the best dye-bearing species. In Turkish times indigo was cultivated in the basins and pump-schemes of the north, and several old concrete fermentation and settling tanks are still to be seen. The industry was defeated by the advent of the aniline dyes towards the end of the last century.

VII. FRUIT CROPS

Most of the information in this section was supplied by Mr. T. D. Bevan, Inspector of Pomology to the Sudan Government.

DATE PALM. 'Nakhla'; fruit, 'belah', 'tamr'. *Phoenix dactylifera* L.

'There is among the trees one that is pre-eminently blessed, as is the Muslim among men; it is the date palm.'—Mohamed.

The reverential attitude of the Semitic world towards the date palm is understandable, 'for its economic importance to the desert dweller as the source of both food and shelter is even greater than that of the coconut palm to the Polynesian'. The physiological requirements of this dioecious

tree are well summed up in the Arab saying that it must have its feet in the running water and its head in the fire of the sky. Hence its restricted geographical distribution.

History

In his *Manual of Tropical and Sub-Tropical Fruits* (Macmillan, 1934) Popenoe writes:

'*Phoenix dactylifera* is commonly supposed, following the study of O. Baccari, to be a native of western India or the Persian Gulf region. Evidently, long before the dawn of history, it was at home in Arabia, where the Semites seem to have accorded it religious honors because of its important place in their food supply, its dioecious character, and the intoxicating drink which was manufactured from its sap, and which in the cuneiform inscriptions is called "The drink of life".

'Traditions indicate that when the Semites invaded Babylonia they found in that country their old friend the date palm, particularly at Eridu, the Ur of the Chaldees (Mughayr of modern maps) whence Abraham set out on his migration to Palestine. It is even suggested that the Semitic immigrants settled at Eridu, which was then a sea-port, on account of the presence of the date palms, one of which was for many centuries a famous oracle-tree. Several competent orientalists see in the date palm of Eridu the origin of the Biblical legend of the Garden of Eden.

'In very early times the palm had become naturalized in northern India, northern Africa, and southern Spain. From Spain it was brought to America a few centuries ago.'

Date cultivation in the Sudan probably goes back thousands of years. Some of the superior varieties, however, are said to have originated in Algeria and to have been imported from Upper Egypt three centuries ago. Others are Arabian types probably introduced about the same time. Insecurity and tribal strife until recent times, and primitive methods of propagation, doubtless have contributed to the slow spread of culture of these good types.

In this century the late Col. E. S. Jackson set a good example in date culture in his garden at Mansurkotti, and in 1935 Mr. T. D. Bevan, who had worked with Col. Jackson, became date expert to the Government to set up nurseries and begin the drive for good date propagation among the cultivators. The late Professor Silas C. Mason did tours of inspection in 1913 and 1924 and contributed a valuable report (*Date Culture in Sudan*, Sudan Government, 1925).

Distribution

In order to bear good fruit the date palm needs high temperatures, low humidity and rainfall, abundant sunshine, and ample water to the roots. Thus it is limited to arid areas of artificial irrigation or of abundant underground water such as may occur in river valleys and oases. Rain at pollination interferes with setting; rain as the fruit ripens causes rot, dropping, and splitting. Frost can be withstood over a short period. There are believed to be about 100 million date-trees in the world, of which some 30 per cent. are in the neighbourhood of Irak, the Shatt el Arab being particularly famous. Egypt has about 10 million trees, and yet imports large quantities of dates.

The counted trees of the Sudan are about 1,700,000 and the total is

probably under 2 million, of which nearly four-fifths are north of Atbara and, by reason of rainfall, comprise the effective crop. By comparison with other date-growing countries the Sudan may (though it is debatable) be too hot and too dry to produce the best quality in soft varieties, but is exceptionally well suited to the production of dry dates. In addition to the river valley there are date palms in the oases of Silima west of Wadi Halfa, El Qa'ab west of Dongola, El Kheiran with Bara near by, and at Kuttum and other places in Darfur. In 1942 the census figures, which omit Kordofan and a few places of known low production, stood as follows:

District	*Trees*	*Tax* £E.
Wadi Halfa	501,328	6,925
Dongola	316,455	4,730
Merowe	436,789	6,549
Berber	291,370	2,913
Atbara	4,096	41
Shendi	59,562	596
Khartoum	11,892	..
Blue Nile	5,650	..
Darfur	4,867	..
Kassala	1,430	..
	1,633,439	£E.21,754

In the census any stem over 5 ft. in height is counted, whether solitary or off-shoot, and males are included.

The 350,000 people living along the river from Berber to the Egyptian border are mainly peasant cultivators to whom the date is food, drink, building material, and cash. The capital value and annual increment are used by the grower as security similar to a banking account—a more stable form of wealth than the Baggari's cattle.

Growth

Variation in the soil, and quality and supply of underground and surface water, are reflected in the yield and well-being of the palms, which locally are believed to be comparable with the sons of Adam in health and illnesses governing the span of life.

Seedlings grow readily and are very hardy. Being dioecious, the date cannot breed true from seed. Half the seedlings will normally be males, and among the other half, however good the female parent, it is long odds against the emergence of a tree with good quality fruit. The seedling date (generally, but by no means always, self-sown) is the curse of Sudan date culture.

A general characteristic of the family Palmaceae is the absence of branching, but there are exceptions, of which two are common in the northern Sudan, the date and the dōm palm (*Hyphaene thebaica* Mart.). In the date the lateral branches arise at the base of the tree, and these offshoots ('shatla'), if removed, planted, and tended in the proper manner, will take root and produce independent trees. It is this capacity for vegetative propagation which makes possible the maintenance of varieties or clones of trees true to type.

Male and coarse type trees generally grow more vigorously than good types. Rate of growth depends on variety and cultural conditions. Small crops may be attained 3 or 4 years after planting, and the offshoots may then have attained a stem height of 4 or 5 feet. Full bearing should be attained in 7 to 10 years. A vigorously growing tree will produce 10 to 20 new leaves per annum and show a height increase of 2 to 3 ft. Offshoots left on the parent retard its rate of growth and tend to postpone the first appearance of flowers. Production of offshoots is to some extent at the expense of fruit production. Slow growth is usual on heavy soils. A tree may continue to bear for 60 or 70 years.

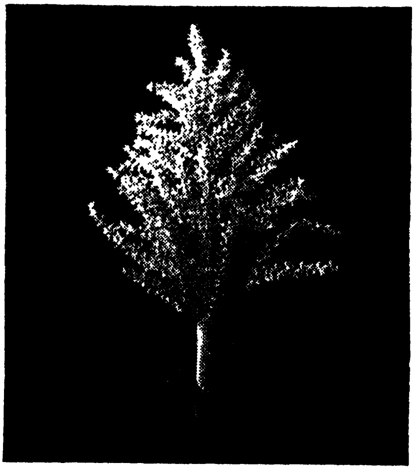

FIG. 135. Male flower of date-palm.

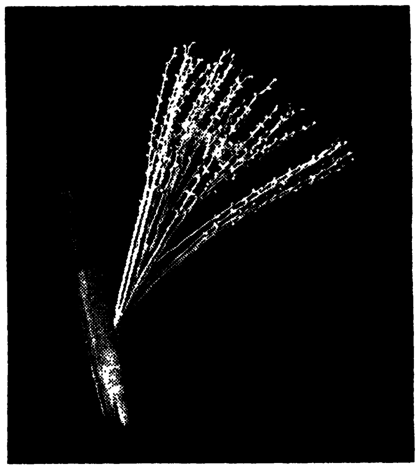

FIG. 136. Female inflorescence of date-palm with fertilizing sprig of male inserted.

Pollination

By nature the date palm is anemophilous or wind pollinated, but as only 2 per cent. or so male trees are allowed by the grower, hand pollination of every female spadix is a necessity.

The origin of the pollen is important. Some authorities state that it affects the size, quality, and time of ripening of the resulting fruit. Although Sudan experience does not wholly confirm this view, it recognizes wide variation in potency of pollens, so only males of proven worth should be used. It follows that male trees should not be allowed to survive at random but should be propagated, like females, by offshoots from a known good parent.

When the male spadices open (or are about to open) they are cut off and stored in a shed for use as required. Thoroughly dry pollen is said to retain its quality for years, and may be kept in a bottle and applied on wads of cotton-wool. Locally, a male inflorescence kept for several months is believed to be stimulated by soaking, prior to use, in a 'muwasa' made of dura flour and water. The male flowers are closely set on numerous clustered branchlets about 6 in. long, and the pollen falls off copiously on shaking.

The female spadices are broader than the male, the branchlets are several times as long and are not so densely clustered, and the flowers, which are less conspicuous, are spaced along the branchlets. Each palm produces ten to thirty spathes, several of which open at a time, necessitating four or five visits from a nimble youth whose payment is often one bunch per tree for pollinating and subsequently cutting down the bunches when ripe. Two or three branchlets of male inflorescence are tied together and inserted between the branchlets of each female spadix as soon as it bursts open. Inclusion of a sprig of an aromatic weed, 'mehleb' or 'haza' (*Ruta tuberculata* Forsk.), is believed by some to promote

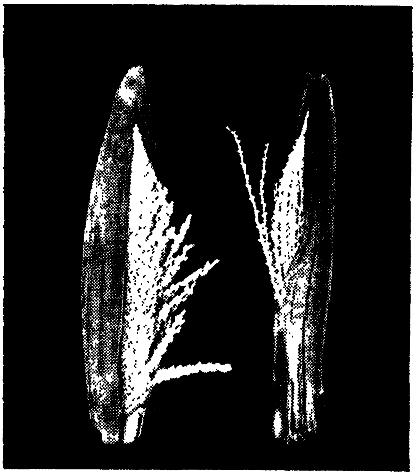

FIG. 137. Male (left) and female (right) date spadices recently burst.

co-operation of 'difficult' females. (The plant is also used as a simple against sterility in women.)

Flowering appears to be brought on by the cold weather and generally occurs from January to mid-March. In Khartoum and southwards, where the temperature falls during the rains, it is not uncommon to see trees bearing two crops a year.

Fruiting

The female flower is tripartite, but after pollination only one carpel persists to develop into the fruit. If not fertilized, the female will usually bear thin-fleshed seedless fruits known as 'sīs'. Sometimes all three carpels develop in this way, the resulting triplet arrangement being readily recognized. These do not ripen properly and are generally fed to animals. If a male spadix is left uncut on the tree it may exceptionally bear similar rudimentary fruits, and it is perhaps this phenomenon that gives rise to the belief that sex reversal sometimes occurs and can be induced in the male by firing the base of the tree. The male of that other dioecious fruit, the papaw, may become monoecious, hermaphrodite, or wholly female, but there is no authenticated record of the date palm behaving thus irregularly in the Sudan.

When the stalks have fully elongated, the bunches may be brought down below the leaves and supported by forked sticks or by tying to the leaf-stalks above. This makes harvesting easier and prevents breaking of branchlets, abrasion by wind movement, and damage of the fruit by leaf-spines, but, like bagging sweet varieties against bird damage, it is only occasionally practised.

The general date-harvest is in September, but the time of picking varies widely with variety and the use to be made of the fruit. Harvesting

FIG. 138. A thicket of Barakawi dates. These are much too thick to produce a reasonable crop, but owing to the local laws of inheritance it is difficult to introduce a reasonable cultural practice on private lands (*photo R. G. Fiddes*).

of early soft dates starts in June; dry dates are left to ripen to dryness on the tree, and there are late maturing varieties whose harvest continues until April. 'Rutub' is the name given to dates picked and eaten green, generally of the Medina or some Meshrig varieties.

Varieties

A soft date is one in which the sugar content is sufficient (about 60 per cent.) to prevent fermentation and to allow of its being preserved and used in a moist condition. One or two very soft kinds ferment easily and are eaten straight off the tree. Some, perhaps most, soft varieties may be dried and traded as dry dates, but the real dry varieties are those that naturally ripen to dryness on the tree without a succulent phase.

Gaw, *Gawa* is a loosely applied term. Some growers apply it to any tree that is not a Barakawi, but generally it denotes seedling origin or a tree grown from an offshoot of a coarse, self-sown type of parent. Thus all but a small proportion of 'gaw' dates are of low value, and about half

the date-trees of the Sudan can be so described. In the former Dongola and Halfa Provinces about 28 per cent. palms are 'gaw'; in old Berber Province 83 per cent., and south of that about 99 per cent.

Barakawi is the most numerous among the good dates and, numbering nearly 600,000, is easily the most important. Professor Mason wrote, 'The Sudan has in the Barakawi one of the few first class dry dates in the world if it is grown, harvested and marketed at its best'. It finds a ready sale in Egypt under the names 'Sukkoti' and 'Ibrimi' and forms the bulk

FIG. 139. Barakawi dates on freehold land are generally far too thick to produce a good crop (*photo R. G. Fiddes*).

of the export. It predominates in Merowe and Dongola, does not occur south of Abu Hamad, and in Wadi Halfa district is outnumbered only by the

Gargōda, another dry date, inferior to Barakawi but hardier, and numbering about 195,000.

Gondeila totals about 80,000 trees, of which Wadi Halfa claims 77 per cent. It is an excellent date which may be treated as dry but which, when specially picked and prepared, makes a very good soft date.

Bint Ahmōda is similar to Gondeila but slightly superior. There are only about 25,000 trees of this variety, of which two-thirds are in Wadi Halfa and most of the remainder in Dongola.

Abid Rahīm resembles Gargoda in being a dry date inferior to Barakawi but hardier and more easily propagated. Most of its 37,000 trees are in Berber district.

Mishrig wad Lagai is an excellent soft date numbering about 9,000 trees, mostly around Abu Hamed. Normally used soft, but can be dried and bagged.

FIG. 140. A clump of Barakawi dates (*photo R. G. Fiddes*).

FIG. 141. Gondeila dates at the Nuri demonstration farm (*photo R. G. Fiddes*).

July and August is doubtless based on the availability of water to the 'sāqiya' at that time.

The newly planted shoot is killed by thirst unless the soil is kept permanently moist. This may involve watering at intervals ranging from a day to a week according to the nature of the soil, method of irrigation, the weather, the degree of shade, and the shelteredness of the site. A temporary breakdown of pump or water wheel is liable to cause heavy loss unless resort can be had to hand-watering. This period of close irrigation continues until the shoot is well rooted, maybe nearly a year for

FIG. 146. Date offshoots or 'shutil' are better planted and cared for in a nursery prior to final planting. This nursery is at Nuri (*photo R. G. Fiddes*).

new offshoots and a few weeks for transplants from nursery to garden. Thereafter the watering intervals can be extended to a fortnight until trunks are well formed when monthly waterings are sufficient. Unlike most plants, the date palm cannot signal its distress by wilting, and thirsty trees, young or old, die without warning.

Culture

Normal practice in the Sudan allows the offshoots to develop on the parent, the result after several years being a clump of trees competing with one another for light, water, and nutriment, and often providing a thicket that harbours rats and other pests. As a result of overcrowding the yield per feddan and the quality of the fruit are both reduced, and failure to put the offshoots to better use is waste of opportunity of expansion. The Government is now advocating and demonstrating the value of single-stem culture, and is supervising the planting of single-stem date gardens on its pumping-schemes in the north. Under the single stem system offshoots are removed as they are formed, unless required for propagation, in which case they are taken as soon as they are fit for plant-

FIG. 147. Using the iron chisel to separate the suckers or 'shutil' from the parent tree. Note the heavy mallets required (*photo R. G. Fiddes*).

FIG. 148. A young plantation of dates and orange-trees in the Nuri demonstration area (*photo R. G. Fiddes*).

ing. The optimum number of trees per feddan doubtless varies with variety and in the bright sunlight of the Sudan may be as high as a hundred. It is doubtful if maximum yield per feddan (as opposed to yield per tree) can be obtained with less than seventy-five trees. At a spacing of 8 by 8 metres (sixty-five trees per feddan) citrus may be interplanted and will do well, but this is not recommended as the frequent all-the-year-round watering required by the citrus is too much for mature date palms, stimulating vegetative growth at the expense of fruiting. Mangoes, with

FIG. 149. A close-up of one of the Mishrig date palms shown in Fig. 142. Planted in 1941. The soil consists of alternating layers of recent silt and fine alluvial sand with potable water at about the nine foot level (*photo by the Dept. of Agr. and For.*).

a lower water requirement than citrus, are more suitable for interplanting, but where mixed fruit farming is the objective the date is best planted in wide belts sheltering other kinds of fruit from the wind and allowing each species to receive its appropriate irrigation. Similarly, undercropping with the perennial lucerne, while excellent for a new plantation, is unsuitable for mature palms. Local practice of growing the early summer dura crop among the dates conforms admirably with the water requirements of the trees, which produce a full crop of fruit with seven or eight waterings during May to August. If water is withheld at this time the yield and size of fruit is seriously reduced and deaths from thirst may occur. Two or more successive poor floods may cause heavy mortality among palms dependent solely on the water-table deriving from the Nile.

The date palm needs high soil fertility and gives a ready response to nitrogenous manures. This is one of the most neglected aspects of date culture in the Sudan and contributes greatly to the low average yield, besides affecting the quality of the fruit. Fifty rotls of sheep dung is

sufficient to restore to health and fruition a sickly palm on thin sandy land. Even the most fertile Nile silts become exhausted under a long-standing date crop, and the digging in of animal refuse every 3 or 4 years is of great benefit. This cultivation and manuring, as well as control of weeds, is best done by under-cropping, preferably with well-manured vegetables, or with legumes. Attention of this kind to a newly planted garden greatly accelerates the rate of growth and shortens the time to first fruiting, in addition to giving an economic return from the land during the fruitless early years.

FIG. 150. Manuring young date-palms at Nuri demonstration farm (*photo R. G. Fiddes*).

But for the sale of 'gerid', the midribs of the leaves, little pruning would be done in the Sudan and there must be doubt that severe pruning is advisable in this fierce sunshine. In particular the Egyptian practice of closely cutting the leaf bases and removing all the coir, leaving a naked trunk, is not advocated here. The time for pruning is after harvest and should consist of cutting off all old yellowing leaves neatly back to the trunk. A leaf may remain healthy for 3 or 4 years, and no active green leaves should be removed, except possibly from the offshoots which may be severely pruned out of the way of undercrops without harm. Removal of the spines from the bases of the leaf stalks facilitates pollination and harvesting.

Yield and Crop Division

A single Medina palm yielded 328 kilos at Nuri in 1943. Yields of 100 kilos per tree are not uncommon, but 50 kilos is a good target figure, and the average ranges from 40 kilos in a good year on a pump-scheme to

5 kilos or less from unirrigated palms following a year of poor flood. The price of dry dates varies widely with demand and variety, but is generally between 5 and 15 P.T. per keila (approximately 10 kilos), so it is a poor tree that will not bring in 20 P.T. a year, or £E.20 per feddan of a hundred trees. On Government irrigation schemes, if the owner of the tree is not the owner of the land the latter is entitled to three-fifths of the crop and the former takes two-fifths and is responsible for constructing whatever surrounding wall or fence is necessary. Water-rates and taxes are divided proportionately. On 'sāqiya' and private pumps the crop is equally divided

FIG. 151. Gondeila date-palms growing luxuriously on recent silt at Nuri. The soil consists of alternating layers of silt and river sand, and there is permanent sweet water at about the 10-ft. level (*photo R. G. Fiddes*).

between landowner, tree owner, and supplier of irrigation water. Each of 'sāqiya', tree, and land may be owned by many partners and the opportunities offered for dispute and litigation, particularly if a partner dies, are not wasted by the local peasantry. Two metres radius from the trunk is the defined boundary of a date palm. The old custom entitling the owner of a tree on another's land to replant if the old tree died is no longer permitted.

Taxation of date-trees, as of other crops, is intended to be one-tenth of the value of the produce, but as the top limit of the tax is at present 2 P.T. per tree good types in full bearing may be paying only a thirtieth or less. The tax is graded down to nothing in proportion as the crop is of low value by reason of location in a rain area or in places where irrigation is difficult, as in the Rubatab south of Abu Hamed where the water wheels ceased to turn when the slaves were freed a quarter of a century ago. In addition to the revenue tax a water-rate of 2 P.T. per taxable tree is likely to become standard practice on Government pump-schemes as productive

date culture spreads. This is already in force in old Dongola Province, but elsewhere water-rates are collected only on the under-crops.

Pests

The common Red Spider, *Tetranychus telarius* Linn., is found throughout the year on many plants, including the date palm. It attacks chiefly the leaves, and the extent of its damage is difficult to assess. It can be easily kept in check by water spraying, but this is never practised by native growers.

FIG. 152. A good crop of dates. Nuri demonstration area (*photo R. G. Fiddes*).

The Date Red Spider, *Paratetranychus simplex*, attacks the immature fruit, impeding development and causing spotting and loss of quality.

Scale insects occur on date palms, but are not serious. Rats can do a lot of harm, but are rarely troublesome in clean well-tended gardens.

Birds, notably the gluttonous bulbul, will take the fruit of any isolated sweet varieties but are not very troublesome in the main producing areas.

Store pests under the vernacular name of 'sus' include the beetle *Oryzaephilus surinamensis* and larvae of *Ephestia* and *Silvanus*. In native practice they are combated by spreading the dates in the sun in a layer not more than 10 in. deep. Dusting with 'Katelsousse' is effective and is becoming increasingly used and fumigation with carbon bisulphide is recommended where facilities exist.

Production of Soft Dates

The common 'ajwa' of the Sudan is obtained by picking when fully ripe, selecting, stoning, and pressing into earthenware jars, skins, or

baskets woven of date or dōm-palm leaflets. The chief faults of this product are its unattractive appearance and variable quality, but its compactness is a convenience that makes it very popular.

At Abu Hamed date factory ripe Mishrig are treated in this way and made up into cellophane packets weighing about half a rotl. Up to 50,000 packets are made each year and find a ready sale. Ajwa in other packs sold from Abu Hamed totals over 400 tons in a good year, the eastern Sudan being an eager customer.

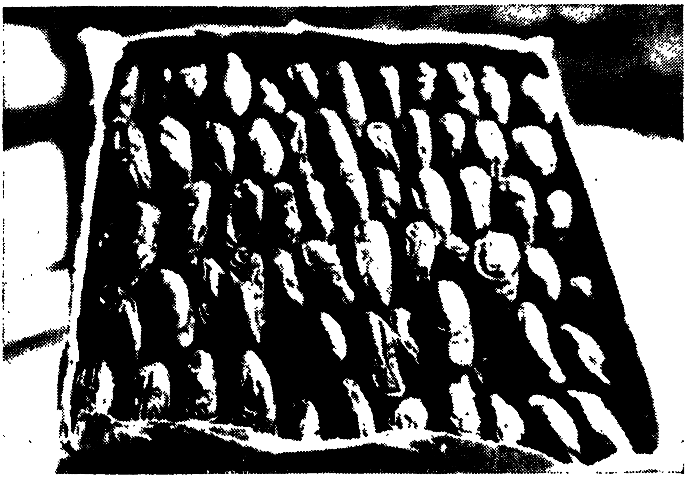

FIG. 153. Dessert dates grown at the Nuri demonstration farm (*photo R. G. Fiddes*).

Mishrig may be allowed to ripen and dry on the tree and then harvested, sacked, and stored. On soaking for a short time in warm water they readily reassume a soft consistency and sell as a good quality soft fruit.

Superior soft dates, from Bint Ahmoda, Gondeila, Kulma, and Deglet Nur, are hand picked just short of ripeness and packed into earthenware vessels ('zīr') which are sealed and left in the sun for a week. They are then decanted on to 'bursh' matting when most of the fruit will have ripened into prime condition. Imperfectly ripened fruits are discarded and the 'zīr' are refilled with good fruit and sealed until required. This gives a good quality product known in Egypt as 'kabīs'.

By-products

Besides its fruit, its security and prestige value, and its shade and verdure in a desert land, the date palm makes other contributions to the economy and well-being of the northern Sudan. The trunk is much inferior to that of the dōm palm as a roof beam, being liable to transverse fracture without warning, but split it makes useful timber for rafters and rough carpentry, and the waste is used for fuel along with pruned leaves, leaf-bases, and flower-stalks. The fibre or coir makes a harsh rope much used for tethering animals, stringing ''anqarīb', and anchoring fishing-tackle. It is this rope that is generally used for tying the pots ('qawadīs')

One of the disadvantages of the mango is the difficulty of hand-picking the fruit. A low spreading tree is required, and in this shape it is less liable to wind damage. So the young trees are topped when knee-high and radial laterals encouraged. Tall trees may be lopped back 8 or 10 ft. after fruiting, without harm, and this may save trunk-splitting.

In the Northern Sudan flowering usually begins in January, and the fruits ripen from June onwards, but some trees are obligingly erratic and flower and fruit in two or three flushes during the year. The fruit should

FIG. 157. Gathering the mango crop (*photo R. G. Fiddes*).

be hand picked, being cut in strings or separately with a length of stalk attached, and should be handled as gently as peaches. Ripening should be anticipated according to the length of the journey ahead. Yields show a wide variation from season to season, and accurate figures are not readily obtainable. One hundred kilograms per tree appears to be a good yield, and the value of a moderate type near Khartoum or a good type (e.g. Alphonse) at Merowe is about 5 P.T. per kilogram to the grower, giving gross receipts of the order of £E.300 per feddan, with cultivation costs lower than those for citrus and little higher than those for dates. The high price is, of course, a scarcity value, accentuated by the fact that the Egyptian crop does not ripen until August, thus permitting an export market at luxury prices.

The proximity of this Egyptian market, the prospects of air transport for luxuries to the capitals of Europe, the large untouched internal requirement, and the modest demands made by the mango tree on the skill, energies, and pocket of the grower, all support the belief that the mango will in future take second place only to the date palm among the fruit

FIG. 158. Orange-trees in the Nuri demonstration farm (*photo R. G. Fiddes*).

crops of the Sudan. To this end the Government is supporting experimental work and nurseries from Dongola to Equatoria Province.

CITRUS FRUITS. *Citrus* spp.

Originally natives of Asia, *Citrus* spp. have spread to all parts of the warm-temperate and tropical world. Watt (*Commercial Products of India*) records that the Portuguese claim to have taken the sweet orange from China to Europe in the sixteenth century, and the Arabic name for this fruit, 'bortugan', is clearly a corruption of Portugal. Citrus have long been known in Arab countries, and the Arabic word 'naranj' gave rise to the English 'orange', Portuguese 'laranga', Spanish 'naranjo', &c.

Citrus aurantiifolia (Christm.) Swingle, the lime, is the invaluable 'limūn beladi' that slakes the noonday thirst, and it is at present the most important variety in the country, being the longest established, most widespread, and by far the hardiest. It is the only one that will stand the scanty and irregular irrigation of the water-wheel, which is often out of action for 2 or 3 months at the hottest time of the year. It grows readily from seed, needs no special care, and frequently yields two crops a year.

Next in hardiness and also long established is the sweet lemon, *C. limetta* Risso. In number and in domestic and commercial importance it is negligible compared with the 'limūn beladi', and most of the earlier introductions appear to have been inferior types, the fruit being insipid to the European taste. The sweeter types are popular locally as in Egypt. It is grown from seed, and is used for budding.

The production of good quality citrus other than the above calls for a regular water-supply and an annual spell of cold weather. It is lack of the former that has doubtless retarded the numerical development of fruit gardens, and lack of the latter that contributes to the often disappointing quality of Sudan produce. In general, places in the north and west, where the winter is pleasantly cool for 3 or 4 months, produce better quality citrus than places south or east of Khartoum. Development of the yellow colour at ripening is also associated with low temperature; Sudan citrus is often quite green when fully ripe.

C. paradisi Macf., the grape-fruit, can be produced in the Sudan to a standard that will bear comparison with the best, but the same cannot yet be said of *C. sinensis* Oskeck., the sweet orange. *C. nobilis* Lour, the mandarin or 'Yusef Effendi', is often propagated by layering or may be grown from seed, but does better if budded. It is hardy, grows quickly and, though somewhat erratic, often bears heavy crops ripening about Christmas. *C. aurantium* L., the bitter orange, 'naringa' or 'laringa', is useful for marmalade and for budding.

In recent years much successful work has been done in Government nurseries, giving trial to introduced varieties that have made their name elsewhere, but probably more could be done in extensive trials of seedlings in the hope of finding new strains suited to the peculiarities of the country. Investigations into cultural methods and choice of stocks have also produced results, but it is too early to be dogmatic. It is surprising how the fruit of a scion, though budded on to the same type of stock, can vary from that of its parent. Slight differences in soil, management, locality,

and health of the tree can have a big effect on the quality of the fruit. A young tree may yield inferior fruit that improves out of recognition when the tree is mature.

Gummosis is not nearly so serious in the Sudan as in some other countries, but propagation by budding is desirable to ensure conformity to type, quickness of maturity, and vegetative vigour. The Sudan lies between the southern countries where rough lemon (*C. limonia* var.) stock is used, and Egypt where the usual stock is the bitter orange. The latter is a useful general-purpose stock in the Sudan, but other stocks give quicker results, particularly on the lighter soils, where rough lemon is superior. Sweet lemon stocks give quick-maturing, heavy-bearing short-lived trees, susceptible to gummosis. 'Limūn beladi' gives results on poor sandy soils where other stocks would fail, and is particularly suitable for sweet oranges, giving strong growth and good quality fruit. The pomelo, *C. decumana* L., grows heartily, showing a wide range in type and quality of fruit, and is being experimented with as a stock.

The technique of budding by the ordinary shield method calls for no special comment. Stocks are budded when 12 to 18 months old. When the scion, which should be lightly staked, is half a metre long it is topped and four or five laterals allowed to develop. When the young tree is transplanted, having attained a diameter of half an inch to an inch, the branches are pruned and leaves removed.

For long-distance transport not permitting heavy balls of earth both root and shoot must be drastically pruned, but where the move is simply from nursery to orchard the tree should be lifted with a ball of earth about 18 in. in diameter.

Permeable well-drained soils are, of course, the best for fruit gardens, and shelter from strong winds is essential. Close planting is desirable for economy in irrigation, sweet oranges at 5×5 metres (giving 160 trees to the feddan) and grape-fruit at 8×8 metres. The latter may be inter-planted with the quicker-growing mandarin, which is later cut out. As with mangoes, weed control and inter-cropping with legumes is beneficial.

Freshly planted trees need water every 4 or 5 days, the interval gradually lengthening to 10 days in the hot weather and 14 days in winter. Citrus trees are very dependent on irrigation water, and even a slight shortage will cause fruit shedding and loss of quality. Water should not be allowed to make contact with the base of the tree lest fungal diseases attack the bark. The crop removes both nitrogen and mineral salts from the soil, and generous manuring is essential to growth, yield, and quality. Results of experiments with artificials are yet inconclusive. It appears to be sufficient to spread and dig in sheep or cattle manure on the surface around the tree in January when the flowers appear and again in June when the fruit is swelling.

Apart from shaping the young tree, as already mentioned, citrus should not generally be pruned, as admission of the sun's ray to the main trunk and branches may result in die-back. Limbs which trail on the ground should be cut off from the main stem, and so should unhealthy branches and unwanted sucker-like shoots growing up the centre of the tree. Any pruning that may be necessary is best done before flowering time.

In the Northern Province January to March is the usual flowering season, with fruit ripening from October onwards, lasting, in the case of grape-fruit, until March. In the central Sudan flowering peak periods are July and November and fruiting peaks are in April and September, but trees are inclined to be erratic, even more so in Equatoria Province, so if transport difficulties can be satisfactorily overcome the Sudan markets can have home-produced citrus in most months of the year. Yields per tree range from 100 to 500 fruits, and compare favourably with those obtained in Egypt and Palestine. With a producer price of 1 millieme per orange and 4 milliemes per grape-fruit the cultivator can show a net profit of £E.10 per feddan in a poorish year. Gardens near town markets are at present obtaining scarcity prices and are netting £E.100 or more per feddan per annum.

Citrus production in the Sudan is in its infancy. In 1943 the total area of mature trees other than limes was believed to be about 40 feddans. In the decade before the second world war the value of citrus fruit imports rose from £E.10,000 to £E.30,000 per annum. This awakening local demand will doubtless increase, and a small export trade may be developed with Egypt whose ripening season is different, but unless a big export trade can be developed, which seems unlikely in the face of better placed and better quality competition, it appears that some 1,000 feddans of citrus is likely to be the economic limit of the Sudan's citrus development for many years to come. The irrigable lands of Northern Province and the Blue Nile, and more restricted areas in Kordofan, Kassala, and Darfur, offer the appropriate field for development, and the southern Provinces will doubtless in time meet their own needs. Experimental, propagational, and distributional work is being pushed ahead as fast as resources permit.

GUAVA. 'Gawafa.' *Psidium guajava* L.

This is a most suitable fruit for the country and is very popular. It provides a valuable anti-scorbutic in a dietary that is often deficient in that element, it grows quickly and yields almost throughout the year, is very hardy, and can survive discontinuance of irrigation for 2 or 3 months.

It is a native of tropical America and little seems to be known about its subsequent history, but it has probably been in the Sudan at least as long as the 'limūn beladi'. Shendi in Northern Province has the most trees, but it occurs wherever there is irrigation, and also in Equatoria Province. It is usually a prolific fruitbearer, and good profits are made. If only for dietetic reasons, guava cultivation should be increased to meet the maximum consumption in all localities.

Propagation is easy from seed or by layering. Isolated trees suffer heavily from the greedy bulbul and other birds, and planting is best done in groves. Six by seven metres is the appropriate spacing, giving a hundred trees to the feddan. Guavas will thrive on a wide range of soils, and in competition with other fruit-trees they will be the successful survivors of overcrowding.

Varieties with a higher proportion of flesh to seed have recently been introduced, both pink- and white-fleshed, and also seedless types which up to the present are rather disappointing in yield.

BANANA. 'Moz.' *Musa sapientum* L.

In India the name plantain is commonly used for all types, whereas in the West Indies the smaller more tasty fruits are called bananas and the larger horn-shaped starchy fruits are called plantains. These latter may have been derived from *M. paradisiaca* L., but are regarded by most authorities as cultivated varieties of *M. sapientum*. Both types are cultivated in the Sudan, the former being more popular. The wild *M. ensete* Gmel., which is widespread in Equatoria Province, has seeds as big as peas and is useless for food. Several introduced types are now thriving there in the wild, semi-wild, and cultivated state, notably a coarse-growing type with long thin fruits whose white flesh is sweet but insipid to the discriminating palate.

In Equatoria Province bananas are a valuable food, particularly in years when locusts have reduced the grain harvest. In the northern and central Sudan irrigated bananas are a welcome addition to the Sudan's limited fruit supply, and a well-cultivated banana patch is a very profitable undertaking. Perennial pump irrigation is, of course, necessary and water requirements are heavy. Complete shelter from wind is essential to the establishment of a new plantation, and the garden should be surrounded, and, if large, divided by shelter-belts. Bananas will not grow in salty or impermeable soils and thrive best where drainage is good.

The land should be deeply trenched and heavily manured, and the shoots planted about 2 metres apart. It is all too common to see gardens yielding infrequent bunches of small cracked fruit. No crop falls off so markedly if neglected, and few crops give such good response to generous treatment. Apart from adequate water-supply, the main essentials are frequent applications of farm-yard manure well dug in, and keeping the number of stems per plant thinned to 3 or 4, each of a different age. Thus each plant is maturing only one bunch at a time, and the result is vigorous growth, fertile stems, and plump healthy fruit. They do better in the central Sudan than in the low humidity of the north, where they will only thrive in the local atmosphere created by an established garden surrounded by trees. They will tolerate part shade and are often interplanted in orchards of other fruit. Properly planted and with favourable conditions they will start to yield in about 9 months. The effects of continued heavy irrigation generally indicate a move to fresh land after 3 years or so.

PAPAW. 'Babaia.' *Carica papaya* L.

This native of the West Indies and tropical America affords another example of the rapid dispersion of the useful plants of that continent soon after its discovery. The papaw thrives in the same climatic conditions as the banana, and it is now established as one of the staple food crops of Equatoria Province. In the irrigated north there are insufficient to meet popular demand.

Although dry seeds will retain their viability for a long time, the best germination is obtained from seeds straight out of the fruit. It is not uncommon to find seeds already germinated inside a ripe fruit. As the

papaw is so quick-growing (it may yield in 6 or 8 months) and is fairly hardy inside a sheltered garden, seeds may be sown out direct in holes about 4 ft. apart. Thinning to three plants per hole should be done early, and the plants singled as soon as their sex is evident. The papaw is normally dioecious. Pollination is effected by insects, so few males are necessary, certainly not more than one in ten. The female tree usually behaves in a conventional manner, but the sex-life of the male may be irregular, particularly if the stem is topped or the roots cut, when hermaphrodite and female flowers may appear on the erstwhile male, and complete sex-reversal is possible.

There is a wide range of types, and a lot of difference in flavour between the best and the worst. As is to be expected with cross-fertilization, degeneration is common. The production of seedling races of good quality that will breed true to type is much to be desired. Vegetative propagation is possible, but also appears to be attended by degeneration of fruit quality.

More than bananas, papaws require a freely draining soil. They are very susceptible to waterlogging, and to reduce the risk of collar-rot they should be grown on mounds so that irrigation water has no direct access to the stem.

The value of the vegetable pepsin, papain, which is present in all parts of the plant, appears to be little known in the Sudan. Elsewhere, juice is tapped from an unripe fruit and rubbed on raw meat to make it tender, or a tough fowl is wrapped in papaw leaves overnight before cooking, or slices of green papaw are put in the water in which the meat is being boiled.

GRAPE VINE. 'Ĕnab.' *Vitis vinifera* L.

The climate of the Sudan is too forcing for viticulture. Many varieties have been tried, and although individual enthusiasts have attained some success, the degree of skill and attention required and the frequency of disappointing results indicate that commercial grape-production in the Sudan is likely to be on a very small scale.

With drastic and timely pruning, preceded by slight droughting, two crops can be obtained in the year. Bird attack necessitates wire cages or the bagging of individual bunches.

PINE-APPLE. 'Ananas.' *Ananas sativus* Schult.

This native of South America grows well in parts of Equatoria Province and is on the increase. It is to be hoped that a good quality fruit may be developed for the northern market. Under irrigation in the northern Sudan the pine-apple, if it grows at all, develops no succulence, by reason of the low humidity and lack of acidity.

FIG. 'Tīn.' *Ficus carica* L.

Figs grow readily in most parts of the Sudan. They are hardy, very easy to propagate by cuttings, and are tolerant of dry periods. Both purple and green types are present. It is difficult to understand why this easily grown fruit has not been developed for the local market. Maybe

bird damage is the chief reason, as without wire cages or individual bags no fruit survives to attain full ripeness. Bird damage would doubtless be less serious if trees were grown in blocks of several feddans; existing trees are thinly distributed. The figs tend to be rather small and dry, and not fully flavoured, but succulent dessert fruits can be obtained if a drop of olive-oil is placed over the mouth of the fruit about 10 days before ripening, i.e. at the time of bagging.

MULBERRY. 'Tūt.' *Morus indicus* L.

The mulberry that grows quickly and hardily in the Sudan has a rather emaciated bristly fruit that ripens through red to black—if the birds will allow. Fresh or stewed it has a delicate flavour that is a welcome change from the monotonous banana. It bears in flushes three or four times a year after heavy pruning. One would have thought that for a small luxury trade it would be worth someone's while to experiment with better introductions and to erect cages against birds.

CAPE GOOSEBERRY. 'Habwa' (Eg.). *Physalis peruviana* L.

This introduction has so far been confined to European gardens, notably for the making of jam or jelly. It grows readily, even in the hot weather, and seed may be sown direct or in boxes. An annual species, probably *P. minima* L., which grows little more than 18 in. high, yields a heavy crop of yellow fruits up to 3 cm. in diameter after 10 weeks or so. These fruits have a harsh flavour when raw, but stewed with plenty of sugar, or canned in syrup, are excellent. The tastier variety, more popular for jam or jelly, is a slower growing, taller, bushy plant, biennial or perennial in habit, and having smaller fruits.

CUSTARD APPLE. 'Qishta.' *Anona squamosa* L.

A native of tropical America, this small tree grows hardily in the Sudan wherever the supply of water is dependable. It often yields in the summer when other fruit is scarce, and its sweet custard-like pulp should ensure a growing local demand as it becomes better known.

POMEGRANATE. 'Romān.' *Punica granatum* L.

This Mediterranean or north African shrub is not difficult to grow under irrigation. It does not bear heavily, nor is the fruit to everyone's taste, but it should be included in every garden for its deep green foliage and its exotic flaming flowers.

MELONS and CANTALOUPS, and also 'kerkade', which collectively constitute the staple fresh fruit of the country, have already been noted as field crops in the preceding section of this chapter.

SOME WILD FRUITS

'Lalob' and 'nebaq' are the fruits of the common 'heglig' (*Balanites aegyptica* Del.) and 'sidr' trees respectively. The latter is *Zizyphus spina-christi* Lam. The jujube, *Z. jujuba* Lam., has been introduced but so far is merely a breeding-ground for fruit-fly. The chief feature of these fruits

is their ubiquity, 'sidr' and 'heglig' being two of the most widely spread plants in the Sudan. The proportion of pulp to stone is small and the flavour is slightly reminiscent of inferior apples. In the north they are chiefly beloved by children and goats, but in the rain areas they are seriously sought if grain crops have failed.

The handsome 'aradēb' tree, *Tamarindus indica* L., has fleshy pods of high sugar content when ripe. They are commonly pressed into an unsightly pulp, along with the seeds which are also edible. They have antiscorbutic and laxative properties which are recognized in local medicine, and a refreshing pleasant tasting drink is prepared from them. The pulp is commonly used for seasoning, and finds a ready sale throughout the Orient. It is anomalous that the produce of this indigenous tree should be known as 'tamar Hindi'—date (tamar) or fruit (thamar) of India.

The baobab, *Adansonia digitata* L., the 'tebeldi', remarkable for the great age and girth to which it attains and the use of its hollowed trunk for water-storage by the western Arabs, has white gourd-like fruits which are spongy, farinaceous, and acid and which are readily eaten, particularly in the rain areas where dietaries are less conservative than in the north.

Grewia betulaefolia Juss., 'gaddēm', a small shrub common in the medium rain belt and occurring as far north as the wadis in Khartoum Province, bears a tasty red berry that makes an excellent stew or jam, not unlike red currant in its sharp flavour and appearance.

The fruits of the dōm palm, *Hyphaene thebaica* Mart., which are chiefly used as vegetable ivory, giving rise to a local button industry, are eaten by some, and the young fruit of the dioecious 'dolēb' *Borassus aethiopum* Mart., is edible, and the hard inner nut can be eaten after ripening if it is planted and allowed to germinate.

The 'qammēz', *Ficus sycomorus* Linn., and other wild figs yield small fruits that are readily eaten by bird, man, or beast.

The tooth-brush tree 'arak', *Salvadora persica* L., and the 'tundub', *Capparis decidua* Pax., are two other common trees that yield edible fruits.

VIII. SOME WILD PLANTS OF AGRICULTURAL OR ECONOMIC INTEREST

Many wild plants have already been mentioned in conjunction with their cultivated relatives. No mention has been made of latex and gum-bearing plants as these must await a treatise on forest products, but it is safe to say that rubber is negligible and gum, particularly that of the 'hashab', *Acacia senegal* (L.) Willd., is very important chiefly for export. The number in brackets following the name of a plant indicates the section of this chapter in which it has been already referred to.

Weeds as Useful Plants

Andrews discusses the principal weeds of the Sudan in Chapter XVII, p. 401, and here a note is included on a selection of them that for one reason or another may, in the right situations, be of economic value.

Nut grass, 'se'id' or 'dīs', commonly *Cyperus rotundus* L., is properly

given pride of place by Andrews as a weed. It may be mentioned that its 'nuts', tubers, or corms are both edible and nutritious and that the herbage has a low feeding-value for animals and is sometimes useful when fodder is in very short supply.

Two weeds of cultivation, the small flowered 'hantut', *Ipomoea cardiosepala* Hochst., and the beautiful white-flowered 'tabr', *Ipomoea* spp. chiefly *I. cordofana* Choisy, which may be a source of exasperation to the hoer, are none the less a joy to camels as fodder.

The milk weed *Lactuca* sp., known locally as 'moleita', that has a trick of persisting from the root like a dandelion, and which is a common weed of cultivation in the central plains, produces leaves that are collected for salad.

The grass 'nagīl', *Cynodon dactylon* Pers., which is one of the most universal weeds on all but the heaviest clays, is also, in the right situations, one of the most useful plants in the Sudan. It is possible that most northern cultivators regard it not as a nuisance but as a supplementary blessing; certainly when American cotton growing was continued in Northern Province into the slump of the early nineteen-thirties the cultivators near towns made more money from the 'nagīl' growing in the cotton than they did from the cotton itself. It is a nutritious fodder, makes excellent hay, and is in keen demand for feeding all classes of live stock. On water-wheel and on small pump schemes in the Northern Province it is often the 'nagīl' growing on the banks of canals and ditches that supplies at times the only fodder for the animals on which the cultivators depend for milk. It has a wide range of forms from a fine surface-creeping type that has not yet been surpassed for tennis lawns to a coarse type with a subterranean rhizome that in open soils may run for yards at a depth of 18 in.

In the south elephant grass, *Pennisetum purpureum* Schum., is sometimes a weed, but is more generally thought of as a valuable final succession plant in the resting cycle of years required for the rejuvenation of worn-out land in areas of heaviest rainfall.

Even 'lalang' grass, *Imperata cylindrica* Beauv. var., in places one of the world's most expensive weeds, is of very considerable economic importance in Equatoria Province in the natural regeneration of some types of worn-out lands and for soil conservation purposes.

The list might be extended, but will be brought to an end by mentioning that the indigenous perennial grass *Sorghum halepense* Pers. or 'adār', which is a well-known weed of cultivation sometimes known as Johnson Grass, is, when under control and in the appropriate situation, a very valuable fodder grass.

Forage Plants

No attempt will be made to discuss that insufficiently studied subject, the forage grasses of the pastoral grazing areas, except to remark that the main constituents of the 'gizzu', the seasonal camel grazing of the north-western desert, are 'nissa' (*Aristida ciliata* Desf.) and 'dirim' (*Indigofera arenaria* A. Rich), and that recent work at the School of Agriculture has tended to show that the Arab grazier may be right in his belief that

certain grasses are more nutritious in the 'ghubash' (desiccated) state than earlier in the year. The same series of observations has helped to explain the summer survival of the northern camel, goat, and Arab donkey by demonstrating the surprisingly high nutrient value of the browsing scrub of the dry savannah and northern wadis.

Prominent among northern forage grasses is the nutritious 'difra', *Echinochloa colona* Link, which grows mainly on river lands and appears in profusion following the receding flood. In parts of Kerma basin in Dongola the flood is succeeded by a dense pure stand of 'keteih', *Trigonella laciniata* L., which looks like a good crop of lucerne, but a bit shorter. In that desert region it is most valuable and commands a high price. 'Handagōg', another and very similar *Trigonella*, and 'atawīl', *Astragalus prolixus* Sieb, are less important leguminous forage plants of Northern Province, and 'gogēb' *Heleochloa schoenoides* Host, is recognized as a good grazing grass.

Food Plants

In the areas with rainfall over 20 in. the people in times of famine eat a wide range of fruits, leaves, barks, and roots. A little farther north one of the main famine foods is the seed of the grass 'korēb', *Dactyloctenium aegyptium* Beauv., and farther north still the fine seed inside the fiercely barbed 'haskanīt' is said to be superior in flavour to the best dura or dukhn, but collecting and handling it must be a painful business.

Mention has already been made of the edible roots of aquatic *Ipomoea* spp. (VI). In Equatoria Province one of the water-lilies has an edible seed which is used as a cereal, and a species of *Hyparrhenia* (Zande 'penze') bears grain larger than that of cultivated or wild rice (I). A species of *Amaranthus* (the West African 'bedi-bedi') is universal in the south and boils into a vegetable tasting no worse than spinach, as does 'tamaleika' (*Gynandropsis gynandra* (L.) Brig.), which is common throughout the rain areas and is also a weed of irrigated lands. In the Zande district there are wild and cultivated *Solanum* spp. bearing bitter fruits which are boiled as vegetables, and the seeds of a semi-wild 'kirkade', *Hibiscus sabdariffa* L. (II), are ground into flour. Among the many wild species of *Ipomoea* of the central rain belt is one with beautiful pale blue flowers, 'milgat', (*I. hederacea* Jacq.), which is sometimes cultivated for the medicinal properties of its seeds.

Miscellaneous

The principal constituent of the extensive 'sudd' vegetation is *Cyperus papyrus* L. This tall handsome sedge was used by the ancient Egyptians for making their papyrus paper, but investigation into its commercial exploitation indicates that it would not be profitable at the present time. It is used on a small scale for local basket- and mat-making.

Among the principal thatching grasses are 'na'al', *Cymbopogon nervatus* Chiov., and 'maharēb', 'marhabēb', &c., *C. proximus* Stapf. Unfortunately the application of the vernacular names (and there are more than those given) is not constant, but perhaps it is commonest to find the species named as above, 'maharēb' usually occurring as a perennial on

sandhills and 'na'al' generally growing as an annual on clay lands. Both are aromatic, 'maharēb' the more so, but the content of essential oil (near Citronella) is insufficient for commercial purposes. Occasionally an extensive pure stand of 'na'al' survives to make good 'harīq', but the 'harīq' grass *par excellence* is 'anīs' (or, in Kordofan, 'bigil'), one of the wild Sorghums (I), probably *S. purpureo-sericeum* Aschers et Schweinf. The essentials for a 'harīq' grass are a pure dense stand and capacity for uniform germination on the first adequate rainstorm. 'Anīs' has the additional advantage, which 'na'al' lacks, of drying quickly to brittleness as soon as the rains are over, and thus being easily broken for fire-lining.

CHAPTER XVII

WEEDS IN THE SUDAN

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'God did not will that the way of cultivation should be easy.'
VIRGIL: *Georgics*, bk. I, l. 121.

WEEDS, which are essentially unwanted plants occurring among cultivated crops, are injurious for a number of reasons. They compete with the crop plants for water, mineral nutrients, including the all-important nitrogen, and sunlight. The effect of removing weeds from uncropped land in the season before it comes under a crop has been described on page 482. Many weeds are plants that under natural conditions would not be able to survive competition with the natural flora. Under cultivation, however, where the natural flora is kept in check and competition is reduced to a minimum, they are able to thrive and perpetuate themselves either by seed or underground tubers.

Weeds can be divided into two principal classes, viz. those that provide their own sustenance by means of roots and leaves, and those that are parasitic and dependent on their host plant (usually the crop plant) for the whole or part of their food-supply.[1]

A. WEEDS THAT PROVIDE THEIR OWN FOOD-SUPPLY

Among these are:

(*a*) *Cyperus rotundus* Linn.

This sedge, known in the Sudan as 'se'id' grass and in other parts of the world as 'nut grass', is one of the most troublesome and persistent weeds of all cultivated land in the Sudan, being prominent on the cultivated 'gerf' land at Wadi Halfa as well as on the rain cultivated land of Equatoria Province. It is a pest in most tropical and subtropical countries and has established a reputation as one of the most intractable of weeds. It is a perennial able to persist during periods of drought by means of underground tubers. These tubers have an extensive and deep root-system which penetrates to layers of the subsoil where there is a constant supply of moisture. By this means the tubers are able to survive during periods of drought, later to produce their aerial growth when climatic conditions become suitable. The method employed in the Gezira cotton area to control this pest is described at pages 477 to 482.

The tubers, though by far the most important means of survival of this pest, are not the only means. Seed plays an important part in the dissemination and perpetuation of this weed. Freshly gathered seed shows only about 1 per cent. germination, but after a period of maturation this increases to 25 per cent. or more. Irrigation water in the Gezira cotton area has been shown to carry seed to cultivated land from plants existing on

[1] For a discussion of weeds in canals see p. 484.—*Editor.*

the canal banks. There is no means of controlling seed dissemination by canal water except by weeding the canals before the nut grass flowers. The extent of this plant on canal banks is, however, so great that weeding to prevent seeding would be an impossible task.

(*b*) *Imperata cylindrica* Beauv. var.

This grass is a pest only in the cultivated land of Equatoria Province. Though some varieties of this plant are used for soil improvement, the bulk are formidable weeds. It is a perennial grass with narrow sword-shaped leaves and having a head surrounded by long white hairs giving the whole a silvery appearance. There appears to be no efficient method of control for this weed except that of continually weeding the land. It is said that in the Sudan this grass cannot compete with the natural flora, and that it is killed when the natural grasses are allowed to cover the land for a number of years.

(*c*) *Sorghum* spp.

These annual grasses, collectively known under the Arabic name 'adār', occur in most parts of the Sudan and form one of the principal constituents of the grasses which are burnt under 'hāriq' cultivation (see page 292). In appearance 'adār' grasses are like open-headed dura plants, but their grain is not eaten.

(*d*) *Miscellaneous*

While 'sei'd' grass (*Cyperus rotundus* Linn.) is the most important pest in the Gash cotton area, another plant called 'mordēb' (*Paspalidium desertorum* Stapf) also causes a considerable amount of trouble. This grass is a tufted perennial arising from a stout creeping rhizome, with a trailing stem throwing up branches with grey-green leaves covered with a waxy bloom. Its control would appear to consist in deep ploughing the land during the dry season, when the roots supplying the necessary water for perennation will be severed and the plants would die.

In the Gezira cotton area, apart from 'se'id' grass which is its principal pest, occur minor weeds such as the perennials *Rhynchosia memnonia* DC., a climber with grey silky appearance and small yellow flowers, *Ischaemum bracyatherum* Fenzl, a densely tufted grass over 3 ft. high, and *Withania somnifera* Dun, a bushy woody herb with dark green leaves, small pale green flowers, and scarlet berries. The annual weeds in this area are many, but the commonest are the white-flowered convolvulaceous creeper *Ipomoea cordofana* Choisy, the strongly scented *Ocimum basilicum* Linn., and *Corchorus* spp.

B. Weeds parasitic on Crop Plants

(*a*) *Striga hermonthica* Benth. (Arabic 'būda')

Of the parasitic weeds by far the most important is *Striga hermonthica* Benth. This plant is a semi-parasite in that it produces green leaves and has a rudimentary root-system: it is thus not wholly dependent on its host plant for its food-supply. The host plants of this parasite in the

Sudan include all *Sorghum* spp. so far tested, maize, and some wild grasses, e.g. *Cynodon dactylon* Pers. (Arabic 'nagīl').

The parasite is of importance because it causes a serious reduction in the yield of the sorghum crop, and in cases of severe infestation only stunted plants with practically no grain are produced.

The 'buda' plant is usually about 15–18 in. high and has a spike of attractive purplish-red flowers of varying depth of colour. Its seed is minute and large quantities are produced by a single plant.

Ungerminated 'buda' seed can remain viable in the soil for at least five years, while the seed of a near relative of this plant causing heavy damage to the maize crop in South Africa has been shown to remain viable in the soil for fourteen years. The seed will only germinate when stimulated by excretions from the roots of certain plants. These plants are not always host plants but include cotton, ground-nuts, 'lubia 'afin' (*Dolichos lablab* Linn.), 'lūbia hilū' (*Vigna unguiculata* Walp.), Dukhn (*Pennisetum typhoideum* (Burm.) Stapf and Hubbard) in certain soils, besides *Sorghum* spp., its normal host plant. If the germinated 'buda' seed is unable to find a host plant it dies. It is obvious, therefore, that the growing of these unparasitized crops on infested land must in time rid the land of 'buda' seed, but the process would undoubtedly take a number of years.

There is as yet in the Sudan no rapid control for this parasite. Research is in progress at present to devise means of dealing with this pest. Continuous hand-picking of the plant before flowering will help to rid the ground of the seed, but it is essential that the plant be weeded before flowering since green ovaries will on drying produce viable seed. Breeding a resistant type of sorghum appears at the moment the only hope of control.

(*b*) *Orobanche* spp.

There are two species of *Orobanche* parasitic on crops in the Sudan, viz. *O. ramosa* Linn. and *O. cernua* Loefl. var. *desertorum* Beck. These plants are true parasites in that they derive their total nourishment from their host plant. They are parasitic on market-garden crops, e.g. peas, beans, carrots, tomato, and 'bedingan' (*Solanum melongena* Linn. var.), and on a few weeds. The widest range of host plants is shown by *O. ramosa* Linn. They only occur in abundance in the Northern Province, particularly in the Wadi Halfa district. They are not at the moment of great importance but may develop in the course of time. No control measures are practised except hand-pulling of the parasite.

(*c*) *Cuscuta* spp.

These occur in all parts of the Sudan, but only in the Wadi Halfa district are they a minor pest on crops, where they occur on onions and peas. Hand-pulling and burning of both parasite and host plant are the only methods of control in practice.

Chapter XVIII

LOCUSTS IN THE SUDAN

By R. C. MAXWELL-DARLING, B.A.

'Nothing is more certain and notorious than this that much hurt and damage hath been known to come from small contemtible creatures which otherwise are of no reckoning and account. . . . Also in Affrick the people were compelled by Locusts to void their habitations.' From Holland's translation of PLINY'S *Historia Naturae*, Bk. 8, chap. xxix.

LOCUSTS are the most serious pest of crops in the Sudan, which is one of the countries in Africa most frequently invaded by locust swarms and where breeding frequently takes place on an enormous scale.

Of the numerous kinds of locusts found in various parts of the world there are two which ravage the Sudan. The first is the Desert Locust (*Schistocerca gregaria* Forsk.), which swarms over the whole of Africa to the north of lat. 12° N. and in the arid parts and highlands of East Africa. All territories of the Middle East, together with Arabia, north-western India and Persia, lie within the range of the desert locust, swarms of which sometimes reach as far north as Turkey and Russian Turkestan.

The other species which seriously affects the Sudan is *Locusta migratoria migratorioides* Rch. and Frm. This is variously known as the Tropical Migratory or African Migratory Locust, and was christened Hairy-chested Locust when it appeared in the Sudan in 1930. A combination of the first two names best describes it, as this species is apparently confined to tropical Africa, where it may breed anywhere except in the extreme north where there is no rain, and in the rain-forest areas where conditions are probably too humid to suit it.[1]

Two other kinds of locust also deserve mention. The Tree Locust (*Anacridium moestum* Serv.) is indigenous to the Sudan, but rarely forms large swarms. As it feeds mainly on leaves of trees it hardly ever causes damage to crops. A solitary swarm of the Red Locust (*Nomadacris septemfasciata* Serv.) appeared from the south in 1937 and travelled northwards as far as lat. 17° N., where it dispersed. This locust is a well-known scourge of Africa south of the Equator, but this is the only record of its having penetrated into the Sudan.

History of the Desert Locust in the Sudan

There is no doubt that this locust has occurred periodically in the Sudan since time immemorial, but there are few definite records until after the reoccupation in 1899.

From this year until 1913 records are scanty, but swarms were present between 1904 and 1907, in which year the Locust Destruction Ordinance

[1] I personally prefer the simplicity and precision of the name Hairy-chested Locust and find all other names confusing. There are, taking Africa as a whole, several well-known locusts that live in some part of the tropics and that habitually migrate, but only one of them has what a layman can recognize as a hairy chest.—*Editor.*

was brought in. From 1908 to 1912 the country seems to have been free of locusts, as the few reported were probably Tree Locusts. In 1913, however, swarms appeared again and the swarming cycle continued until 1917.

Between 1917 and 1926 few locusts were reported. Some of the reports are known to have referred to Tree Locusts, and it is quite possible that this species may have accounted for all reports from the interior.

During this period, however, the Desert Locust showed spasmodic activity on the Red Sea littoral, and it was here that the next outbreak began in the winter of 1925–6. By 1927 swarms were invading the interior, and the swarming cycle reached its peak in 1929, after which year it started to decline until 1933, when swarms were last seen in the interior.

Incipient outbreaks occurred on the Red Sea littoral during most winters from 1933–4 onwards, but these were suppressed.

The next swarming cycle began in 1941 and probably originated in Arabia as far as the Sudan is concerned. The interior was invaded in 1941, but the infestation was on a limited scale in this year and 1942. In 1943, however, summer breeding was heavy and widespread and the winter breeding on the Red Sea coast the heaviest on record. In 1944 the summer breeding was on the largest scale ever known, and the winter breeding, though less than the previous winter, was more widespread than usual.

It is too early to say what 1945 will bring, but the invasion by flying swarms occurred early and breeding had already started in June.

History of the Tropical Migratory or Hairy-chested Locust in the Sudan

The first record of this locust in the Sudan, since the reoccupation in 1899, was in 1930, when swarms entered Darfur Province from the west and spread eastwards. Some old men recognized this locust and called it *qābura* (as distinct from *qabūra* meaning small grasshoppers), stating that it had occurred in the country some forty years previously.

From 1930 to 1940, this locust occurred every year in varying numbers and caused great damage to crops. The infestation in 1931 was much heavier than in 1930, but during the next five years it gradually declined until in 1936 only two swarms entered the country and there was no breeding. In 1937, however, the west and south were again infested, and in 1938 the whole of the Sudan except for the rainless areas was seriously affected, and over £E.600,000 worth of damage was estimated to have been caused to crops. The situation improved from 1939 onwards, and in 1941 there was no breeding. From 1942 to 1944 this locust was absent from the Sudan, but a few swarms have been reported in 1945.

Life-history

The life-history of both locusts is similar. The female lays a packet of about 100 eggs in moist soil. The nymph when it emerges from the egg is enclosed in a skin and thus wriggles to the surface of the ground, when it casts the skin and emerges as a small wingless locust. The nymphal or hopper stage lasts 5–8 weeks, during which the insect sheds its skin five times before it becomes the winged adult locust.

The swarms of young adults rarely breed in the area where they became

adult, but nearly always migrate to a fresh breeding-ground. The reason for this is that their breeding is connected with the rainy seasons, though what causes them to migrate is not known.

Seasonal Migrations and Breeding Areas

Desert Locust. Although breeding can take place in the comparatively moist highlands of Kenya, Ethiopia, and Eritrea, the desert locust belongs essentially to arid countries. The question so often asked as to what it finds to feed on in such desolate regions is explained by the fact that it breeds only during the rainy season, and that if the rains are poor, little breeding occurs.

Sexually immature swarms begin to invade the Sudan from the north-east and north-west in May and June. When the rainy season proper begins in July, the locusts become sexually mature and breed. How long these immigrant adults live and how many times they oviposit depends on the conditions of the particular rainy season, but as a rule, most eggs are laid between mid-July and mid-August, after which the adults die.

Although swarms may penetrate far south, breeding rarely takes place south of lat. 12° N. Between lats. 12° 30′ N. and 13° 30′ N. early breeding often takes place, as the rains begin earlier in the south, but this breeding is usually on a fairly small scale. It is when the rains are good in the more northern latitudes that the heaviest infestations of hoppers occur, as conditions are then most suitable to the species. Soil conditions south of lat. 12° N. are not favourable to oviposition as the desert locust prefers to lay its eggs in sandy soil. The climate also at these latitudes is too moist to suit this insect.

We should mention here that some breeding occasionally takes place in the south-eastern corner of the Sudan. This is the north-western edge of the arid zone of Kenya and does not really affect the Sudan.

The majority of the hoppers, if not destroyed, will have acquired wings in September. At the end of this month and during October the country rapidly dries up, and the young swarms emigrate to the winter and spring breeding-grounds. The swarms which originally come from the west usually penetrate only as far as western Kordofan, so that the bulk of the immigrant swarms come from the east. It is a curious fact that the off-spring of the former return to the north-west, while the offspring of the latter return to the north-east.

The winter and spring breeding-grounds are the arid regions which receive rain during these seasons. These are the Mediterranean coastal region of Africa, the Red Sea littoral, the whole of Saudi Arabia, Trans-jordan, Palestine, Iraq, Syria, and occasionally Turkey. The most eastern and western spring breeding-areas are not mentioned here as they do not usually concern the Sudan. For the same reason the Kenya–Southern Ethiopia–Somali area is not discussed. All these territories receive winter and spring rains, but usually winter breeding, that is to say between November and January, is confined to the Red Sea coast, as the interior of Arabia and the more northern parts of the area concerned are too cold at this season for development to take place fast enough. If sufficient early rains occur on the Red Sea coast, large-scale breeding will take place

and produce swarms to reinforce the original swarms which will breed when warmer conditions occur in the rest of the winter–spring breeding-area. During the two swarming cycles about which we have much information, swarms were moving about and breeding in the Sudan, Eritrea, and Arabia for several years before the northern parts of the Middle East were attacked.

The swarms bred during the spring return to the south in May and June when the rains are over in the winter–spring breeding-areas. The Sudan is then invaded and breeding begins again during the summer rains.

There may be two main generations in the year, one in the summer and one in the spring; or at the other extreme there may be two summer generations, one winter generation, and two spring generations. The number of generations depends largely on the rainfall conditions of the year in question.

Tropical Migratory or Hairy-chested Locust. In a year when conditions favour it, this locust can breed in the Sudan almost throughout the year. Breeding may start at the onset of the rains in the extreme south in March or April. The swarms move northwards as the rainy belt extends in that direction, and breeding will take place around lat. 7° N. in May and lat. 10° N. in June. From July to September this locust invades the area of the desert locust, and the northern limits of its migration and breeding depend on the rainfall. In 1938 swarms penetrated as far north as lat. 18° 30′ and bred there, but this is exceptional. At the end of the short northern rainy season the young swarms move southwards, breeding again in the central Sudan in October–November and in the south in November–December. During January and February, the country is generally free of swarms which probably move into the Congo and Uganda at this period. Owing to the overlapping of generations which occurs it is impossible to say how many generations may take place in a year.

How Outbreaks occur

It is a well-known fact that locusts occur in cycles. After a number of 'locust years' the cycle comes to an end, and is succeeded by a number of years when no swarms appear until the new cycle begins. For a long time it was a mystery how the swarms arose again and whence they came. This has now been partly elucidated by investigations carried out in various countries and by numerous workers.

The first important discovery was that locusts have several 'phases'—the swarming phase, the solitary phase, and intermediate phases. The solitary and swarming phase differ considerably in appearance. Hoppers of the former are green while those of the latter are yellow with black markings. The structure of the adults of the two phases is also so different that they were regarded as distinct species, until it was discovered that one form could be transformed into the other.

If the offspring of swarm adults are reared individually in separate cages, they acquire the characteristics of the solitary phase. Conversely if the offspring of solitary adults are reared crowded in one cage, they turn into the swarming phase.

During non-swarming years the locusts do not die out, but persist as scattered individuals of the solitary phase, which would not be recognized as locusts by those accustomed to seeing these insects only in swarms.

The phase theory naturally gave a pointer to the problem of how swarms originate at the beginning of a swarming cycle, and it is first necessary to consider how the transformation from the solitary to the gregarious phase takes place in nature.

The Desert Locust. In the case of the desert locust this transformation was first observed near Port Sudan in 1926, and has since been further studied. The following is a description of how outbreaks occur in this area.

The rainy season on the Red Sea littoral, unlike that of the interior of the Sudan, occurs between November and March and is extremely erratic. At Port Sudan, for example, the annual rainfall varies between 19 and 422 mm., while the normal is 106 mm.

Numerous wadis run from the adjoining mountains into the sea, and most vegetation occurs in these wadis. They usually spread out into deltas of varying size near the sea, and cultivation is usually restricted to these deltas and to the beds of the wadies where these are not too stony. Apart from the cotton grown in Tokar delta, the main crop is the tall bulrush millet (*Pennisetum typhoideum* (Burm.) Stapf and Hubbard) which grows well in very sandy soil.

The solitary phase of the desert locust can always be found on the Red Sea littoral, particularly in the deltas. The reasons for this are complicated as the locusts are attracted to dark objects (in this case vegetation), and once among the vegetation they are kept there by their reactions to various factors.

When the solitary locusts begin to breed at the outset of the winter rains, the effect of this concentration is to produce a much higher population of hoppers within these areas than would be the case if their parents were scattered all over the coastal plain.

This is the first factor favouring the crowding of hoppers which is necessary for the transformation from the solitary phase.

The next factor is the preference of hoppers for dense ground vegetation. This produces a further concentration in certain localities within the larger concentration areas. These localities are usually millet fields which are not properly weeded. Among the dense growth of weeds are some bare patches of soil on which the hoppers sun themselves at certain times of the day. This causes them to congregate which affords the mutual stimulation which increases their activity, and this initiates the change of phase.

Eventually the hoppers if sufficiently numerous begin to march about together and may leave the concentration area. Once this happens the factors which tended to make the individuals congregate no longer operate, and the tendency is for the band of hoppers to disperse unless they are so numerous and have also changed their phase so completely that their mutual gregarious tendency is stronger than the dispersal tendency acting on the individuals.

This is an important point as a certain amount of phase transformation and formation of loose bands of hoppers occurs frequently on the Red

Sea littoral without cohesive flying swarms being produced. The hoppers in this case dispersing and beginning to change back to the solitary phase.

An outbreak which means the beginning of a new swarming cycle requires a large increase in population on which the concentrating factors can work. This introduces the last important factor, which is the rainy season.

Sexual maturation depends on the beginning of the rains, and if the rainfall is heavy and prolonged larger numbers of eggs are laid than in a season of poor rains. The coastal rains usually begin in November and are often practically over by the end of December. In this case the first winter generation which becomes adult towards the end of January will not become sexually mature, and most of them will not survive until the following rainy season.

If, on the other hand, the rains continue during January and February the numerous young adults will mature and quickly produce a second generation which means an enormous increase in population. The resultant bands of hoppers will be large and dense and will be able to resist the dispersal tendencies arising when they leave the outbreak centres. When they become adult in April they will emigrate in swarms from the winter rain area, and, if they reach the interior, will breed on the summer rains in July, thus starting the swarming cycle.

It is therefore exceptionally heavy, prolonged, and widespread winter rains which can be expected to produce a serious outbreak. Unless all three conditions are satisfied, it is unlikely that swarms sufficiently large and numerous to start the swarming cycle will be produced.

The question naturally arises as to whether outbreaks can occur in the interior of the Sudan. The evidence is insufficient to give a definite answer on this point, but such as is available is against the probability. The largest populations of solitary locusts in the interior are found on the sandy soil, particularly the fixed sand-dunes or 'qōz'. The vegetation of these areas is of the desert-shrub type characterized by an even distribution of low perennial tussock grasses or undershrubs of which some are more or less evergreen.

This uniformity does not present any features to cause concentration of adults or hoppers, and even cultivation where it occurs does not seem to act in this capacity. It may be mentioned, however, that solitary locusts are distributed over wide areas where there is no cultivation near enough to exercise any influence over them. Further investigations are needed, but the fact remains that, during the period 1934–40, all swarming activity in the Sudan was confined to the Red Sea littoral; and *there* it frequently occurred, necessitating some control measures in most years.

As one progresses southwards down the western coast of the Red Sea, rainfall conditions begin to alter owing to the appearance of the April–May Abyssinian 'little' rains. On the Arabian side conditions are also different from those on the African side, and the picture as drawn for the Sudan will doubtless need modification before it is applicable to these areas.

The foregoing description of the origin of outbreaks on the Red Sea coast does not take into consideration the question of the migration of

solitary locusts. It has been almost conclusively proved that in India the solitary individuals migrate from winter-rain areas on the Indo-Persian coast to the spring- or summer-rain areas in the neighbouring interior. This migration is an essential factor in the production of outbreaks in this area, as the initial multiplication takes place in one zone and the final generation resulting in the change of phase in the other. Whether migration of solitary locusts over long distances plays a part in the Red Sea outbreak area is not yet known, but it is improbable that it is an essential factor.

The Tropical Migratory or Hairy-chested Locust. It is almost certain that the only outbreak area of this locust is the inundation zone of the river Niger in French West Africa.

The details of how the process takes place are not complete and we need not review them here.

It is of interest to note that solitary individuals of this locust are known to change their phase and produce small bands of hoppers in various regions of Africa including the Red Sea coast, but genuine outbreaks have never been known to occur except in the Niger outbreak area.

Damage to Crops

The desert locust feeds on a large number of plants, whereas the tropical migratory locust feeds only on graminaceous plants which include cereals. In the Sudan, however, the majority of the crops eaten by either species consists of grain crops—the millets *Sorghum* and *Pennisetum*—although serious damage is sometimes caused to cotton and sesame by the desert locust.

Most of the grain crops of the Sudan are rain-grown, and the main cultivation area lies between latitudes 11° and 15°.

In the case of the desert locust, the immigrant swarms never cause much damage. When they appear in May and June, there are few crops growing in the regions which they penetrate. When the young crops germinate there are sufficient wild plants growing at the same time to provide food for the locusts so that the crops are not particularly selected at this stage.

If hoppers get into a crop, they do the most severe damage, but the greatest losses are caused by the young flying adults prior to and during their emigration in September and October. At this time the wild vegetation is drying up while the crops are still green, and the millet grains in the milk stage are greedily eaten by the locusts.

The hairy-chested locust causes damage to grain crops wherever it appears, but the heaviest losses occur at the same season as for the desert locust, when the swarms of the former are moving south from the northern rain areas.

The actual amount of damage done is very difficult to estimate. The area of rain cultivation naturally varies from year to year, and is not known at all accurately. The crop expected depends mainly on the rainfall, which is often very local in its distribution. The cultivators could probably give a fairly accurate estimate of locust damage, but it is not in their

interest to minimize it. The following figures, compiled from various sources, are, however, given for what they are worth.

Year	*Amount of loss in £E.*	*Area involved*	*Species of Locusts*
1938	600,000	Most of Sudan	Tropical Migratory
1939	135,000	Central and southern Kordofan and Darfur; Fung area of Blue Nile Province; Southern Sudan	,, ,,
1940	600	One district of Darfur; one district of Equatoria Province	,, ,,
1941	Negligible	..	Desert Locust
1942	,,	..	,, ,,
1943	119,000	Darfur Province; Tokar Delta	,, ,,
1944	390,000	Area north of lat. 14° 30′ and east of long. 32° 00′	,, ,,

Locust Control

There is at present no satisfactory method of dealing with flying swarms. It is sometimes possible to poison large numbers with bait, and flame-throwers have been successfully used on occasions, but these measures are not suitable for general use against large numbers of large swarms. Experiments in dusting adult swarms with a contact poison from aircraft have been carried out within the last few years, but the results are still insufficient for any conclusions to be drawn.

Digging up the eggs from the ground is a method of attack which is often employed, but it requires too much labour to be recommended, and is in any case impracticable on a large scale in deserts.

It is therefore against the hopper stage, which lasts about 6 weeks, that the main campaign has to be waged. Primitive methods such as beating with branches, burning the hoppers or driving them into trenches are still employed in some countries, but are not efficient and require an enormous amount of labour.

It is generally accepted nowadays that the best way of killing hoppers is by the use of poison bait. The bait consists of a carrier such as bran, mixed with water and sodium arsenite, and molasses is sometimes added. The bait is spread in front of the advancing hoppers who eat it and die. In the Sudan the mixing of the bait is done at a central factory, and the ready mixed bait sent out to the provinces. It then only requires the addition of water to be ready for use.

Important advantages of poison bait are that it is economical in labour —an important point when working in trackless deserts; it is simple, not requiring machinery or other apparatus; and it does not require skilled labour but only skilled supervision.

History of Locust Control in the Sudan

Previous to 1914 there was little in the way of organized locust campaigns, although cultivators endeavoured to protect their crops by primitive methods.

In 1914 poisoning was introduced, the method being to spray the

supplied by the district, a Technical Assistant, an official loaned from another department, or a temporarily employed man. Under each area are a number of centres which are usually in the charge of a temporary supervisor, or sometimes a policeman. Finally there are the posts consisting of one to three poisoning gangs under a post supervisor. In some parts of the country, however, the organization of the campaign is to a large extent in the hands of the Local Government authorities who provide most of the supervisory staff.

Paid labour is always employed nowadays, as it is so much more efficient than unpaid labour. When the latter is used, it always results in large numbers of men working inefficiently, which means a waste of labour at a time when it is required for cultivation.

Each post has a number of camels for the transport of equipment from camp to the scene of operations, for fetching water, and for moving to a new site. Camels are also used to fetch supplies of bait if the dump is not too far away.

Assuming that plenty of bait has been distributed during the dry season, motor transport is mainly used for movement of supervisory staff and local transport of bait. But more bait has usually to be brought up by lorry from the reserve at province headquarters to which supplies are sent from the bait factory.

One of the main difficulties which arise is early assessment of the gravity of the situation. The severity of the infestation is often realized only at a stage when supplies have to be rushed up with the greatest speed, unless the hoppers are to get the upper hand.

Another difficulty is the question of adequate supervision. It is impossible for the senior staff to move about fast enough to exercise close supervision with the result that a great deal depends on the efficiency of the centre supervisors.

The success of a hopper campaign is judged by the paucity of the young adult swarms which are formed. If only a few small loose swarms appear, success may be said, for all practical purposes, to be complete. In the case of a severe infestation, a mortality of over 99 per cent. would probably be necessary to achieve this result.

In 1944 and 1945 the Army rendered great assistance to the campaign in the Sudan. Wireless Units were loaned by the M.E.F., while the Sudan Defence Force, in addition to lending vehicles to the civil organization, also carried out operations in some areas.

Locust Policy

This may be considered in several stages:

(1) Control measures near crops.
(2) Control measures in the desert, to prevent the young flyers invading the crop areas.
(3) Control measures everywhere breeding occurs.
(4) Control of outbreak areas.

The first stage need not be discussed and the second has been shown to pay in the Sudan as explained in the section on damage.

The third stage has been attempted against the Desert Locust during the period 1943–5 as exemplified by the campaigns of the Middle East Antilocust Unit in Saudi Arabia and southern Persia. The main object of such measures is to reduce the number of locusts which will emigrate to breed elsewhere, even though they may not be likely to cause much damage themselves. Another effect which might be produced would be to bring the swarming cycle to a premature end. Up to the present the campaigns have not been successful enough to enable conclusions to be drawn on these points.

The fourth stage—the control of the outbreak areas—provides the only hope of any permanent solution of the locust problem. A large amount of investigation is still needed before we know all the areas where outbreaks can occur and the details of the process in different areas.

Once this is discovered, it may prove possible to keep a permanent watch on the outbreak areas and prevent any incipient outbreaks developing into the beginning of a new swarming cycle.

It is hoped than an organization to carry out this work may be developed by the co-operation of the territories concerned in the near future.

CHAPTER XIX

ORGANIZATION OF AGRICULTURAL RESEARCH AND THE EXPERIMENTAL FARMS

By the late FRANK CROWTHER,[1] D.SC., D.I.C., A.R.C.S.
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'And he gave it as his opinion . . . that whosoever could make two ears of corn, or two blades of grass, to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together.'

SWIFT, *Gulliver's Travels: Voyage to Brobdingnag.*

ORGANIZATION OF AGRICULTURAL RESEARCH

AN understanding of the changes which have taken place in the organization of agricultural research as the Sudan has developed is necessary for easy reference to the reports and publications of the various sections engaged in research. Some of these changes may appear, from the alterations made in nomenclature, to have been drastic, but none of them in effect interrupted the continuity of the experimental work.

In the very early years there were few areas where irrigated or rain crops were grown on a large scale for export, and thus the poverty of the country allowed of little research work. It was chiefly through the munificence of Mr. Henry S. Wellcome that a beginning of research was made possible as early as 1903, for it was he who founded the first scientific organization in the country, the Wellcome Research Laboratories in Khartoum, which were incorporated in the Gordon Memorial College and, in the realm of agriculture, concerned themselves at first mainly with chemical and entomological work.

The oldest of the existing experimental farms is that at Shambat, opened in 1904 as part of the Department of Agriculture and Lands. Here trials were made on numerous crops. The work was greatly extended in 1912 when this farm was transferred to the Education Department, and became closely associated with the Wellcome Laboratories. Buildings, including the first agricultural laboratory in the country, were erected at Shambat through a generous bequest from Sir Otto Beit, and were staffed from the Laboratories, all botanical work being transferred there from Khartoum. The chemical and entomological work, however, remained in Khartoum, but the whole of the research was under the Director of the Wellcome Laboratories, and this continued until 1919.

In 1919 the Shambat Farm and the botanical work, with the newly opened Gezira Research Farm near Wad Medani, were all placed in the Department of Agriculture, though the chemical and entomological work started at the latter farm continued to be conducted by research staff responsible to the Director of the Wellcome Laboratories.

To ensure closer collaboration all workers concerned with Gezira

[1] The writer acknowledges his indebtedness to T. Trought for the use of his notes on the history of research in the Sudan.

problems were incorporated in 1931–2 into the Gezira Agricultural Research Service with headquarters at the Gezira Research Farm, the staff being seconded to it from the Department of Agriculture and Forests and from the Wellcome Laboratories. In April 1935 this organization became assimilated into the Department of Agriculture and Forests and was known as the Agricultural Research Service, all concerned in agricultural research being transferred to it. From that date the title Wellcome Laboratories ceased to apply to any of the staff engaged in agricultural research. This rearrangement was accompanied by other changes in nomenclature: for instance, the Gezira Chemical Section became the Soil Research Section, but the personnel remained the same. The Controller of the Gezira Agricultural Research Service became the Director of Agricultural Research, and his powers were widened to include the formulation of programmes of experimental work for other parts of the Sudan, though, regarding field work, only that at Shambat and the Gezira Research Farm was actually carried out by the research staff. Even under this arrangement the Government Botanist and Chief Plant Breeder remained at Shambat until 1936, when all the work became centralized at Wad Medani.

In 1938 the title was changed to Agricultural Research Institute, and since 1944 the staff have constituted the Research Division of the Department of Agriculture and Forests under a Chief, Research Division, instead of a Director of Research. From 1931–2 onwards, through all the changes, the Gezira Research Farm has remained the headquarters of the agricultural research work, and many of the staff, while being answerable to changing departments, have pursued without a break the investigation of their particular problems.

Publication of Results

A complete bibliography of the publications on the agricultural research work up to 1946 is included as an appendix to this volume (v. pages 922–38). Frequently, where the material has been suitable, papers have been published in scientific journals, mostly in England, but much valuable information has appeared only in the reports of the various sections published by the Sudan Government.

The early chemical and entomological work up to 1911 is to be found in four finely presented volumes of reports of the Wellcome Research Laboratories. The earliest detailed agricultural and botanical work, done at the Shambat Farm from 1912 to 1914, was published under the title *Pump Irrigation in the Northern Sudan, with Special Reference to the Cotton Crop*. Thereafter the Government publications have been mostly annual reports, appearing within those of the departments concerned.

Details of the reports of each section are included in the bibliography. Up to 1925 most reports were only typewritten, although summaries of the chemical and entomological work, and, occasionally, of the work at Shambat, were included in the printed reports of the Gordon Memorial College. From 1925 to 1928 the combined reports of all sections were printed under the title *Agricultural Research Work in the Sudan*, but in the years of economic depression they were once again typewritten. When,

Now there is no longer a rigid rotation, and the area under cotton has been reduced. Experiments with American cotton are now sown early in June and those with Egyptian cotton in July or August. The spacing is 45 cm. between holes on ridges 90 cm. apart. The interval between irrigations varies from 10. to 15 days according to the weather. Usually much of the later crop is destroyed by pink bollworm (*Platyedra gossypiella* Saund.), and in recent years the cotton has been almost limited to that required for plant-breeding work. So long as Shambat remained the headquarters of the Government Botanist numerous field experiments on

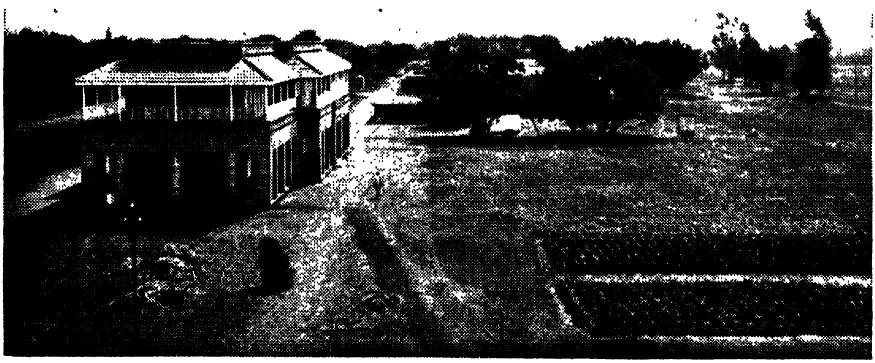

FIG. 159. The headquarters of the Gezira Research Farm of the Department of Agriculture at Wad Medani.

the manuring of cotton were carried out, but these ceased in 1935–6 with the transfer of the Botany and Plant Pathology Section to the Gezira.

During the early years of Shambat, trials were made on a variety of crops including wheat, Egyptian bersīm (*Trifolium alexandrinum* Linn.), lucerne, various kinds of 'lubia', cowpea, pigeon pea, and cereal fodders including dukhn, maize, dura, and Sudan grass. The fibres sunn hemp and sisal were also tried. In recent years few crops have been grown other than cotton, wheat, 'bamia', and lucerne, except that, as a war measure, there has been an extensive and successful production of vegetables under the direction of L. A. Palmer.

THE GEZIRA RESEARCH FARM (lat. 14° 24′ N.; long. 33° 29′ E.; alt. 1,335 ft.)

The Gezira Research Farm is not only the centre for research work on the Gezira Scheme but has been, since 1931, the headquarters of all agricultural research work in the Sudan. When the pump-schemes at Taiyiba and Barakat, started respectively in 1911 and 1914, had proved that the Egyptian type of cotton could be grown successfully in the Gezira, it was decided by the Sudan Government that, 'considering the large issues at stake, a supplementary but smaller farm was necessary

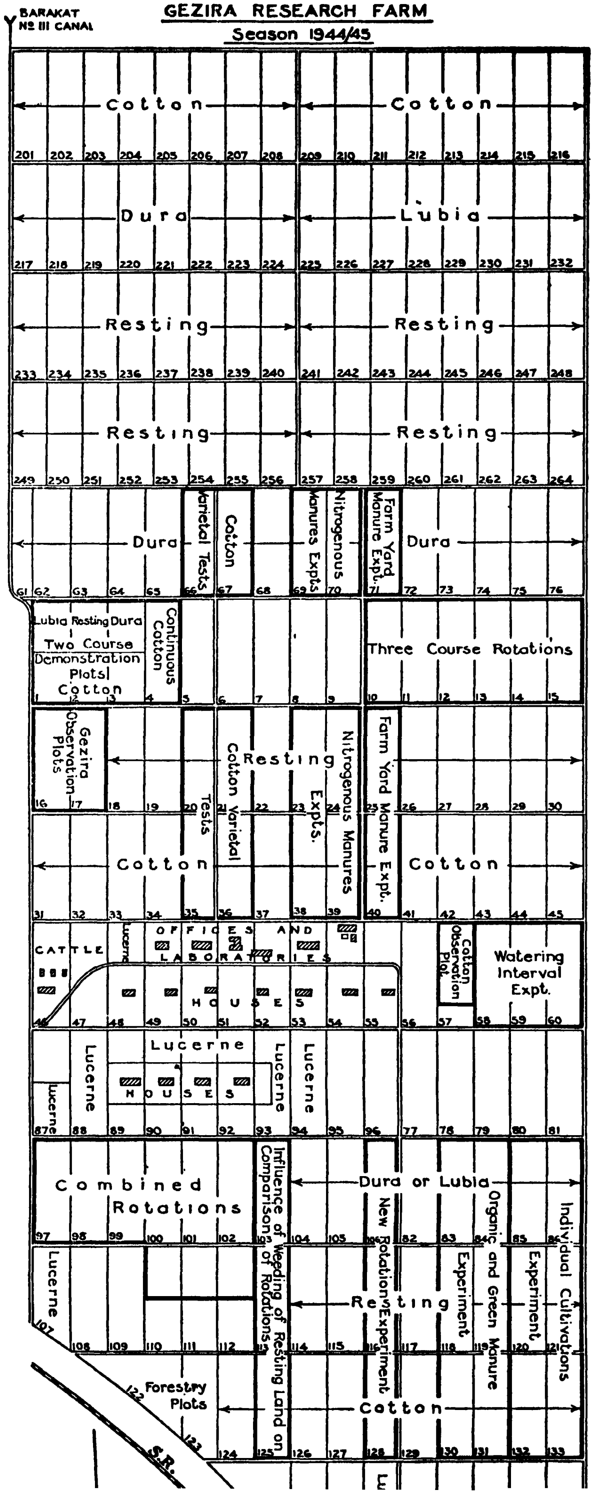

FIG. 160. Plan of the Gezira Research Farm, showing the position of the permanent experiments. In each case the boundaries of these experiments enclose all the land used over the three years of the rotation.

where research work would be carried out in more detail'. As a result the Gezira Research Farm was started in 1918 three miles west-south-west of Wad Medani, the Government administrative centre of the Gezira Scheme and the capital of the Blue Nile Province.

The site was chosen for the combined advantages of proximity to Wad Medani and availability of irrigation water, then supplied by the pumps at Barakat. The position proved convenient as to supply of labour from the town, but the land was low lying and, before the introduction of irrigation, had been heavily over-cropped with rain dura, especially since 1914 when it was used as a spill-area for surplus water from the Barakat canals to the south. The earth-banks, or 'terūs', used in growing rain dura in the Gezira were levelled when the area was canalized, together with the numerous roads converging on Wad Medani, but they created strips of soil whose higher fertility is still visible each year in the cotton fields, marring the uniformity of the land. In recent years, and with the inclusion of new land, the average yield of the farm has improved and is now comparable with that of the central Gezira.

Farm Layout. The present layout of the farm and the position of the principal permanent experiments and buildings are shown in the accompanying map (v. Fig. 160), and in the aerial photographs (Figs. 161 and 162) taken in 1929. The original gross area was 350 feddans,[1] and the gradual extension is indicated in the following table of the land available for crops:

Season	*Plot nos.*	*Previous history of site*	*Additional area (feddans)*	*Cumulative area (feddans)*
1918–1919	1–60	Rain dura	300	300
1925–1926	61–76	S.P.S. irrigated crops	78	378
1928–1929	77–86	Rain dura	50	428
1929–1930	87–96	,, ,,	50	478
1930–1931	97–133	,, ,,	185	663
1934–1935	134–142	,, ,,	45	708
1944–1945	201–264	S.P.S. irrigated crops	307	1,015

The extensions have included both land previously irrigated and land which had grown only rain crops. In almost all cases the plots are of 5 feddans with standard dimensions. This uniformity greatly facilitates the conduct of experiments. The layout of the plots and the method of irrigation are clearly shown in Figs. 160 and 162. The feeder-channel (Arabic: 'abu 'ishrīn', lit. the father of twenty, referring to the original cost of 20 piastres for digging a standard length of 20 metres) shown in the left bottom corner brings water from the canal to the field-channels (Arabic: 'abu sitta', lit. the father of six, referring to the original cost of 6 piastres), of which there is one to every 5-feddan plot. For uniform watering each plot is divided into 20 strips (Arabic: 'angaia'), each pair being watered by a 'gadwal' fed from the field-channel. For experiments a sub-plot may consist of 2 strips, as in the case of the main rotation experiments, or frequently a strip is divided into 5 sub-plots, providing 100 sub-plots to an area of 5 feddans.

[1] 1 feddan = 1·038 acres = 0·420 hectare. Other weights and measures will be found in the glossary.—*Editor.*

FIG. 161. Aerial photograph of the Gezira Research Farm, December 1929, showing laboratories and houses, subsequently increased in number. To the left is a series of cotton experiments (Plots 34 to 45), and in the centre, beyond the most distant house, is the Old Observation Plot (Plot 57) with sub-plots of cotton, 'lubia', and resting land. Behind the line of trees the commercial cropping is typical of the Gezira Scheme on the old 3-course rotation. The first number (90 feddans) is growing cotton, the second has 7/16ths dura and 9/16ths 'lubia', and the third is resting *(taken by the Royal Air Force, Khartoum, whose help is gratefully acknowledged).*

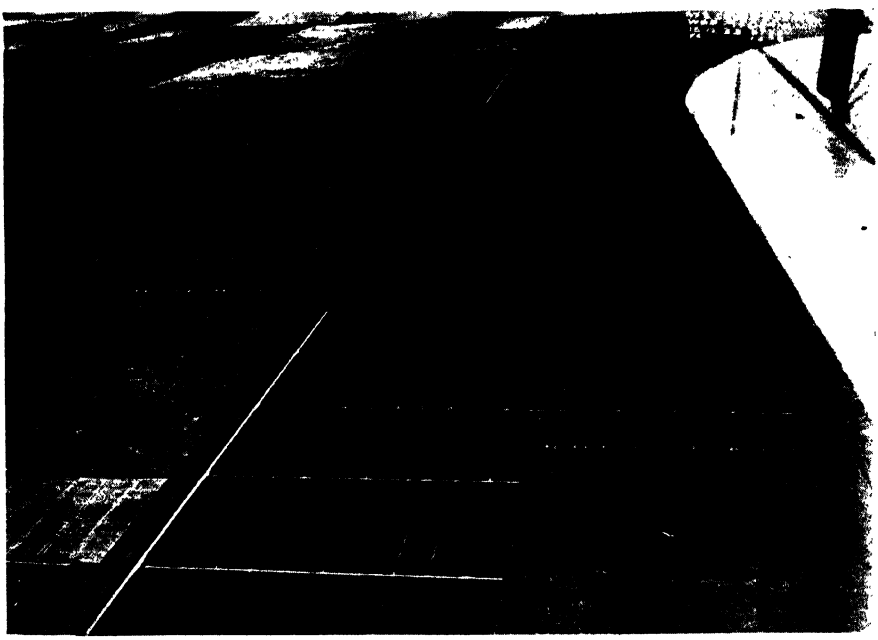

FIG. 162. Aerial photograph of the Gezira Research Farm, December 1929, showing cotton and other experiments. Plots 1 to 3 in the foreground have cotton on their left halves, while

The regular layout of the land, combined with the large number of operations which are performed by hand and the adequate supply of labour and supervisory staff, have made possible the abundant use of recent advances in statistical methods of field experimentation, and the scale of work can be gauged by the numbers of sub-plots harvested separately in a representative year (1942–3), namely 1,826, 819, and 147 for cotton, dura, and 'lubia' respectively, a total of 2,792 sub-plots.

Soil. The soil of the farm, like that of most of the Gezira Scheme, is uniformly heavy, containing 50 to 60 per cent. of clay throughout the top 6 ft., with a structure as described in Chapter XX. The content of easily soluble salts averages about 0·2 per cent. and comprises in the top 2 ft. mainly sodium carbonate, and in the second 2 ft. mainly sodium sulphate; but very large quantities of gypsum (a hydrated form of calcium sulphate) occur in the subsoil. The soil is strongly alkaline (pH around 9·0), and the combination of the sodium salts with the high clay-content explains the low permeability of the soil. As in the entire Gezira, the content of organic matter and nitrogen is small, but so far supplies of phosphate and potash have appeared adequate.

Meteorological Data. Meteorological data averaged for the years 1919 to 1940 (for rainfall to 1942) are summarized below:

	Daily max. temp. (° *F.*)	*Daily min. temp.* (° *F.*)	*Relative humidity 8 a.m.* (*percentage*)	*Rainfall* (*mm.*)*
January .	93·4	57·7	36	0
February .	95·7	59·0	26	0
March . .	101·5	64·0	21	0
April . .	106·2	69·6	20	3·6
May . .	106·2	74·8	31	11·5
June . .	103·1	75·7	48	33·2
July . .	96·1	72·7	67	132·3
August .	92·5	71·8	77	145·2
September .	96·4	71·6	70	54·8
October .	101·5	71·4	50	13·2
November .	98·6	65·1	36	1·0
December .	94·3	59·5	39	0
Mean .	98·8	67·8	43	Total 394·8

* To convert to inches multiply by 0·4. More exactly 1 inch = 25·4 mm.—*Editor.*

The weather is very hot from April to June, as at Shambat, but subsequently Wad Medani is cooler and more humid because of the heavier rainfall—395 mm. as compared with 142 mm. at Shambat. During the rains the nights are cooler at Wad Medani than at Shambat, but the winter is warmer and of shorter duration. The wettest year so far recorded at the Gezira Research Farm is 1929 with 707 mm. and the driest, 1926 with 240 mm. The wettest month is August, and 70 per cent. of the year's rain usually falls in the two months July and August. Water is absorbed so slowly by the Gezira soil (v. Fig. 163, taken after a storm of moderate intensity) that during the wettest period crops, resting land, and roadways are frequently flooded, and rain-water is liable to remain stagnant on the

plots for several days (v. Figs. 164, 165, and 168), so that the crops frequently turn yellow from waterlogging. In recent years a system of surface drains has speeded up the removal of surplus water.

Standard Cultural Practices. Details of the standard practices of cultivation and management for the cotton, dura, and 'lubia' crops respectively are summarized below:

Cotton

Cultivation. By Fordson tractor with ten-tine cultivator, to about 6 in. depth, twice during December to February (v. Fig. 166).

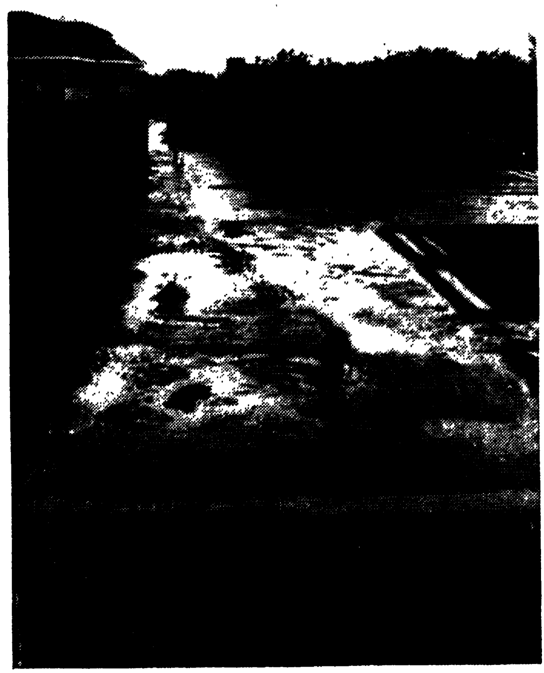

FIG. 163. The Gezira Research Farm, after a moderately heavy storm (*photo F. Crowther*).

Ridging. With ridging-plough drawn by bulls, in March. (The ridges for all crops at 80 cm. apart.)

Sowing. By 'selūka' (native sowing-stick), usually confined to the week starting 13 August (v. Fig. 169).

Spacing. 50 cm. between holes; about 10 seeds per hole.

Thinning. To 3 plants per hole; in one or two stages, completed by the end of September. (One re-ridging by bulls precedes the first thinning, the only bull-operation after sowing, v. Fig. 167.)

Hoeing. All weeds destroyed whilst small by hand-hoeing.

TYPICAL FLOOD SCENES ON THE GEZIRA RESEARCH FARM

FIG. 164. Land prepared for cotton at the Gezira Research Farm, after a moderately heavy storm. The photograph shows also the system of labelling sub-plots and the subdivisions for irrigation (*photo F. Crowther*).

FIG. 165. Flooding after heavy rain of land prepared for cotton at the Gezira Research Farm (*photo F. Crowther*).

Ancient and Modern Implements in use on the Gezira Research Farm

Fig. 166. Tractor cultivation of land for cotton at the Gezira Research Farm (*photo F. Crowther*).

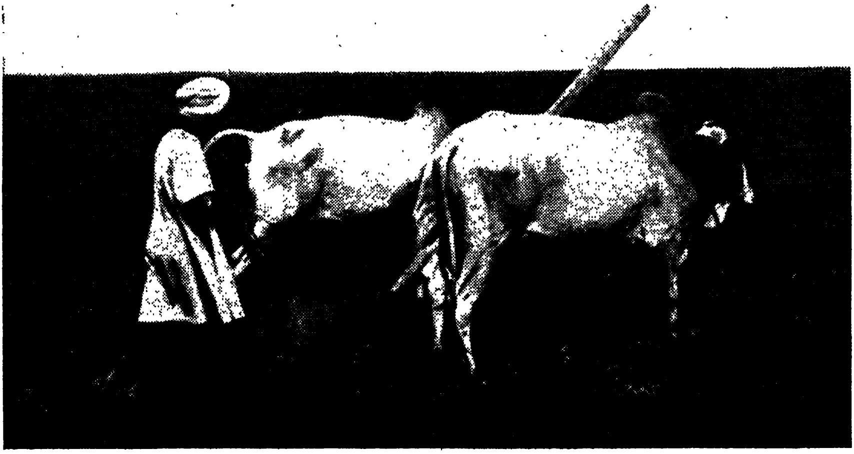

Fig. 167. Re-ridging of young cotton four weeks after sowing, at the Gezira Research Farm (*photo F. Crowther*).

FIG. 168. A young crop of dura at the Gezira Research Farm, flooded by heavy rain (*photo F. Crowther*).

FIG. 169. Cotton-sowing at the Gezira Research Farm. Chains marking the correct spacing are lying in the furrows. Normally the seed is sown on the top of the ridge, but the ridges in the photograph have been damaged by rain driving on them from the left (*photo F. Crowther*).

FIG. 170. A cotton experiment at the start of picking at the Gezira Research Farm, in January. The plants on the two ridges which separate the sub-plots and constitute a belt have just been removed (*photo F. Crowther*).

FIG. 171. Picking a cotton experiment at the Gezira Research Farm. There is one picker to each ridge and one bag to each picker (*photo F. Crowther*).

FIG. 172. Dura receiving its first weeding. August 1942 in the Gezira (*photo M. C. Hattersley*).

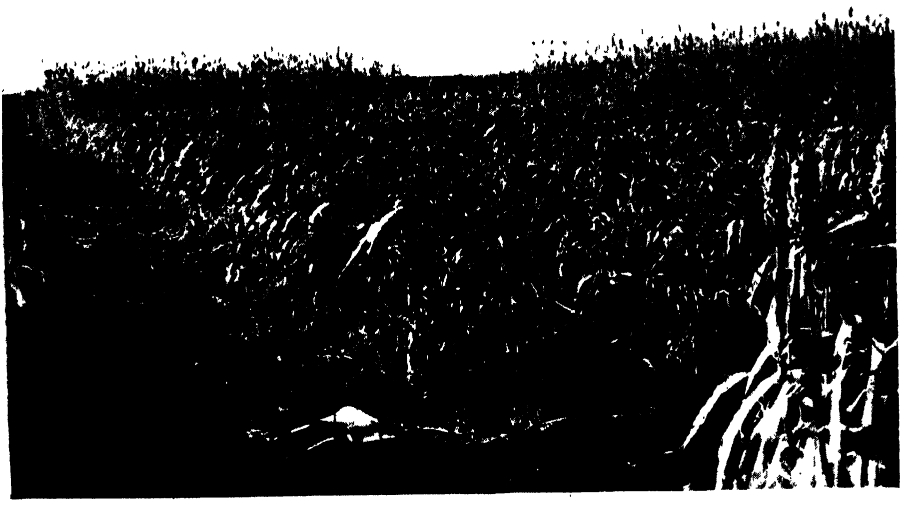

FIG. 173. A dura experiment ready for harvesting at the Gezira Research Farm with plants already removed from the surrounding ridge which serves as a belt. Note, on the empty ridge to the left, the upright shoots of the root-parasite *Striga hermonthica* (*photo F. Crowther*).

Irrigation. Either 4 to 5 days before, or immediately after, sowing, according to rainfall. Irrigation intervals adjusted to the rainfall until late September, after which a 14-day interval for the remainder of the season, i.e. till the end of March.

Picking. Flowering from mid-October; picking from late December. Picking repeated fortnightly as necessary, usually 7 pickings (v. Figs. 170 and 171).

Pulling. Crop removed during April–May by extraction with root-pullers (v. Fig. 227 on p. 553). Plants, including leaf- and boll-debris collected by hand, burnt before 1 June as a measure to reduce survival of blackarm and pink bollworm.

Dura

Cultivation. One re-ridging of the old cotton ridges, by bull-plough, in early July after the rains have broken.

Sowing. In second half of July on the old cotton ridges; about 10 seeds per hole.

Spacing. Like cotton.

Thinning. None.

Irrigation. Usually immediately after sowing, and later according to rainfall; fortnightly from early September to early October.

Weeding. Hand-hoeing of all weeds whilst small and hand-pulling of the root-parasite *Striga hermonthica* Benth. usually necessary from early September to prevent seeding.

Harvesting and threshing. By hand-labour in November (v. Figs. 173 and 174).

'Lubia'

Sowing. In rotation experiments mid-July, the practice formerly general in the Gezira. On rest of the farm in September or October, the optimum time, or in December after removal of the dura crops.

Spacing. As for cotton, but 2 or 3 seeds per hole.

Thinning. None.

Irrigation. Normally fortnightly.

Harvesting. In experiments the fodder cut, and weighed immediately, at 4½ months after sowing.

The cotton crop at the Gezira Research Farm tends to mature and to be picked earlier than the adjacent commercial crop. The only other crop grown regularly, and this on land out of the rotation, is lucerne (*Medicago sativa* Linn.; Arabic: 'bersīm el hegāz'[1]). Wheat has been grown as a war-time measure only.

Rotation. The standard rotation at the Gezira Research Farm has always been cotton once in 3 years, but the cropping between successive cotton crops has varied. Until 1931–2, in the year following cotton the land went under either dura or 'lubia', and was uncropped in the third year. In 1932–3, to provide more crops for experiment and more fodder, the

[1] The Arabic word 'bersīm' means the Egyptian clover. Lucerne in Arabic is 'bersīm el hegaz' or 'bersīm hegāzi'.—*Editor.*

rotation was changed to annual cropping with cotton, dura, and 'lubia' respectively. This marked a departure from the rotation practised in the scheme, where a year's rest always preceded cotton. In 1934–5 large areas of cotton were destroyed by termites and losses occurred also in the following season. As a counter-measure against termites, the rotation was changed to allow once again the year's rest, the change becoming effective for the 1937–8 cotton crop. To produce sufficient dura and 'lubia' and yet retain the resting year, dura was sown in June or July with 'lubia' following it on the same land in December, immediately after the removal of the

FIG. 174. Harvesting a dura experiment at the Gezira Research Farm. The heads are harvested first and the straw later. See also Fig. 190 on p. 475 (*photo F. Crowther*).

dura. This growing of the two crops within the same year, which started in 1935–6, is possible only on the Farm where there are special facilities for obtaining water during the closed period from April to July. Compared with the rest of the central Gezira, the growth and yield of cotton have been satisfactory on the farm, but the yields of dura have been below those of the Scheme where the dura follows a year of rest. The 1944 extension of the Farm is to permit of experiments on the 8-course rotation of the Scheme, which, among other advantages, allows a rest before dura as well as before cotton.

Normally the land is grazed by cattle and sheep at the end of each crop, but the dura-straw is usually consumed away from the plot. 'Lubia', whether sown in July or September, is cut for hay, but that winter-sown is grazed off without cutting between April and June. On the rotation experiments the dura-straw and 'lubia', after being cut and weighed, are returned to their respective plots and consumed there (v. Fig. 175). Otherwise no manure, organic or inorganic, is applied to any crop except

in manuring experiments (v. Fig. 188 for application of ammonium sulphate).

Until 1941 the weeds which germinated and grew on the resting land in the rains in the year previous to cotton were allowed to ripen and dry off, there being no hoeing before October. Now this weed-growth is kept down by hoeing during August and September.

Control of Pests and Diseases. In general the measures used for reducing damage from pests and diseases have been those adopted in the Scheme; but, to keep down blackarm, from 1925 to 1930 the seed was obtained

FIG. 175. Sheep folded on the old observation plot (Plot 57) at the Gezira Research Farm. The first cut of 'lubia' from the crop in the left foreground is being consumed on the adjacent resting land, which will come under cotton six months later (*photo F. Crowther*).

from either Tokar or the Gash Delta, where infection is usually light, and from 1926–7 until 1940–1 the seed was treated with concentrated sulphuric acid. These were additional to the precautions used on the Scheme, which included, in 1931–4, seed freshly imported from Egypt and, from 1931, treatment each year with Abavit B. From 1932 to 1940 much of the land was also flooded annually after the removal of the cotton crop to destroy blackarm-infected debris. To reduce termite damage, in addition to the change in rotation, upon the recommendation of J. W. Cowland several of the permanent experiments have been dressed annually, since 1937–8, with a mixture of Paris green and sawdust, applied in September ahead of the re-ridging.

Stock. The farm herd of cattle and flock of sheep were started to supply animals for ploughing and grazing. The cattle are of a native, 'Kenāna', breed and their numbers average as follows:

Cows . .	35	Bulls, working .	32
Heifers . .	15	Bulls, young .	10
Calves . .	30		

The herd has been improved by breeding and selection, with the dual aim of providing bulls suitable for ploughing and cows with an average milk yield of 500 gallons per year. The milk is of good quality, containing a high percentage of butter-fat. The average lactation period of the cows is about 7 months. Except in the case of first calves, about 350 gallons of milk are produced at each lactation. Concentrates, in the form of dura-grain and oilcakes, are fed only to the milking-cows and working-bulls.

Efforts made during 1928 to 1933 to raise an improved breed of sheep, by crossing Merino rams imported from South Africa with the local types, proved unsuccessful. In 1937 the whole flock was replaced by the Butana breed from the Kassala Province, but these may in turn be replaced by a local breed better adapted to the rigours of the Gezira.

Management. At first the farm was managed by a Board of Control consisting of four members, two appointed by the Sudan Plantations Syndicate Ltd. and two by the Sudan Government, but in 1924–5 the entire control passed to the Government, the Director of Agriculture and the Director of the Wellcome Tropical Research Laboratories being jointly responsible. Now close co-ordination of the research work with the agricultural needs of the Gezira Scheme is assured by the Cotton Research Board which, meeting under the chairmanship of the Director of Agriculture and Forests and including members representing the Administrative Service, Irrigation Department and Sudan Plantations Syndicate Ltd., reviews the annual programmes and results of experiments.

The first laboratory, for entomology, was completed in 1923–4. Other well-equipped buildings were erected at intervals, and in 1935, when the farm became the headquarters of agricultural research in the Sudan, the central library and main block of offices were added. The research staff gradually increased during the same period, the greatest influx at the farm taking place between 1921 and 1931, when V. P. Walley was Chief Inspector of Agriculture. Other appointments followed when the farm became the headquarters of the agricultural research organization, first of the Gezira, and later of the whole Sudan. This organization was headed by M. A. Bailey from 1931 to 1938 as, first, Controller, and then Director, of Agricultural Research, and by T. Trought from 1938 to 1943. From 1944 the research organization became the Research Division of the Department of Agriculture, with H. W. Bedford as its first Chief.

The Research Division is divided into seven sections as follows:

1. Farm Manager	General farm management, including stock.
2. Economic Botany	Flora, plant introduction and the control of perennial weeds and parasitic plants.
3. Entomology	Investigation and control of insect pests.
4. Plant Breeding	Breeding of cotton and improvement of food crops.
5. Plant Pathology	Nature and control of plant diseases and investigations on soil micro-organisms.
6. Agronomy and Plant Physiology	Crop management and the causes of seasonal variation in yield.
7. Soil Research	Survey, classification, and examination of soils.

The heads of all sections are stationed at the farm. There are sub-stations of the Plant Breeding Section at Shambat and Kadugli, and the Entomological Section has field laboratories at Shendi, for the Northern Province, and in the Gash Delta, Nuba Mountains, and Equatoria Province.

Nuba Mountains

Early reports mention trials with cotton in the Nuba Mountains in 1918, but systematic experimental work began only in 1926–7. It has been conducted mainly at Kadugli and Talodi, with subsidiary stations at Dilling, Lagowa, and Um Berembeita. Besides these, in 1938 an area, now known as the Dam Gamad Scheme, was selected near Talodi for investigating the cost of growing crops and the profit therefrom.

Meteorological Data. The sites of the farms were chosen for their proximity to cotton ginneries and administrative centres. Um Berembeita, Dilling, and Lagowa are situated on relatively flat land, but Talodi and, to a less extent, Kadugli lie in basins between hills. The position and total rainfall of these sites are as follows:

Station	*Opened in*	*Position*		*Altitude (ft.)*	*Annual rainfall* (mm.)*
		Lat.	*Long.*		
Kadugli .	1926	11° 00′ N.	29° 43′ E.	1,683	761 (1910–42)
Talodi .	1926	10° 39′ N.	30° 24′ E.	1,412	811 (1915–42)
Dilling .	1936	12° 02′ N.	29° 38′ E.	2,206	682 (1915–42)
Lagowa .	1936	11° 25′ N.	29° 09′ E.	About 2,000	733 (1938–42)
Um Berembeita .	1939	11° 50′ N.	30° 45′ E.	1,870	682 (1938–42)

* 1 inch = 25·4 mm.

All stations receive a much greater rainfall than Shambat and Wad Medani, the annual rainfall at Kadugli being more than five times that of Shambat and nearly twice that of the Gezira Research Farm. The monthly records at Kadugli for temperature and humidity, averaged over the years 1938 to 1942, and for rainfall, averaged over the years 1910 to 1942, are shown in the Table on p. 432.

Kadugli is cooler than Shambat and Wad Medani in summer and hotter in winter. Thus during the main growing season of cotton the mean maximum is about 12° F. lower at Kadugli than at Shambat, whereas at picking time it is about 8° F. higher. The temperature differences and the higher humidity arise primarily from the heavier rainfall in the Nuba Mountains. The temperatures at Talodi and Lagowa resemble those of Kadugli, but those of Dilling and Um Berembeita are stated to be definitely lower.

Soils. In order of the clay-content of the soils Um Berembeita has the most and deepest clay, next come Kadugli and Lagowa with clay soil of brown colour. That of Talodi varies from grey to brown and is on the whole appreciably lighter, although some samples have shown on analysis a high clay-content. The soil of Dilling is the lightest of all, greyish in colour, and containing a relatively high proportion of sand. The soil of

the Kadugli Farm is not typical of the district, for it is unusually silt-like and less alkaline than elsewhere.

All these soils have been formed by the weathering of a granitic type of rock. All tend to be alkaline (pH from about 7·1 to 8·8) and to crack when dry, those with high clay-content cracking extensively. Though they are quite distinct from the Gezira clay, which has a high alkalinity in the surface soil and large quantities of salts in the subsoil, most of them are typical of extensive areas of the Sudan. Because of the more permeable soil and the slope of the land, there is much less flooding from rain-storms than in the Gezira, despite the heavier rainfall.

*Monthly Records at Kadugli**

	Daily max. temp. (° F.)	*Daily min. temp. (° F.)*	*Relative humidity 8 a.m. (percentage)*	*Rainfall (mm.)*
January	97·7	60·8	39	0
February	100·6	65·1	33	2·1
March	102·4	67·1	26	1·0
April	104·2	72·0	36	16·1
May	98·1	73·0	65	78·6
June	93·9	71·8	76	123·5
July	87·8	69·8	88	153·1
August	86·9	69·8	92	153·6
September	90·0	69·1	88	143·7
October	94·8	66·7	80	83·6
November	97·2	62·1	47	6·0
December	96·8	61·7	37	0
Mean	95·9	67·5	59	Total 761·3

All the farms, in common with the whole area, are liable to suffer soil-erosion if the surface is left free of vegetation during the rains. Attempts made so far to discover suitable rotations of crops on the main farms have been handicapped by failure to include an adequate 'resting stage', which in the Nuba mountains means a period when the land is left under grass. In addition to this resting period of several years, most of the farms need additional anti-erosion measures before they can be considered satisfactory for experimental work on annual crops like cotton and dura.

Crops and Cultivation. Ploughing, although not practised by any of the native cultivators, has been introduced on the Government farms for all land coming under crops. Bull-draught is used, but it is a laborious and slow operation as a result of the dry and compact state of the soil. The whole area is ploughed once after harvest, in January to March. From March onwards a series of light cross-ploughings are made, and, after the first fall of rain, another cross-ploughing creates a seed-bed. No animals are kept other than the working-bulls.

The commonest rotations are 3-year, viz. cotton–dura–legume and cotton–dura–sesame. At Um Berembeita and Lagowa and on the Dam Gamad investigation area, resting land under grass suitable for burning,

* The years averaged in each column are given on page 431.

i.e. 'harīq', is included as part of the rotation, but no such resting land is available on the Kadugli, Talodi, or Dilling farms.

The details of cultivation of cotton are as follows:

Sowing. By the local sowing-stick, on the flat between anti-erosion banks, during June or July according to rainfall, the optimum date being after about 75 mm. have fallen.

Spacing. 90 cm. between holes, lines 60 cm. apart.

Thinning. To 3 plants per hole.

Weeding. Normally 3 times, by hand-hoe, among the standing crop.

Picking. Begins early November.

Removal. In March, by cutting at ground level for bollworm control.

Dura, sesame, and ground-nuts are all sown about the same time as cotton and at the same spacing, but they are not thinned. Ground-nuts and sesame are usually harvested in October, and dura from October to December according to the variety.

Pests and Diseases. The cotton crop suffers damage of varying severity from blackarm disease and stainer-bug. Egyptian bollworm (*Earias insulana* Boisd.) also causes some loss of crop. Dura suffers from common smut (*Sphacelotheca sorghi* (Link.) Clint.; Arabic: 'sueid'). Ground-nuts are attacked by termites and by a leaf-spot disease (*Cercospora* sp.). Sesame is liable to suffer severe damage from a bacterial disease, called locally 'marad ed dam' (lit. disease of the blood), caused by *Bacterium sesamicola*.

Experimental Work. There are laboratory facilities for entomology at Kadugli and Talodi. Kadugli, since 1936, has also been the centre for R. R. Anson's plant-breeding work on American cottons, and in 1941 a ginnery for the new types of cotton was erected. Other experimental work has been conducted by the Inspectors of Agriculture, especially by G. F. March, J. R. Burnett, R. T. Paterson, W. A. Porter, H. A. Graves, L. E. James, E. S. Colman, and J. W. Hewison. Apart from pest control, early work was directed towards (*a*) the introduction of new crops and of new varieties of established crops; (*b*) establishment of a rotation to replace the practice of growing cotton year after year on the same land; (*c*) investigation of the value of ploughing; and more recently (*d*) protection against erosion of the soil; (*e*) the place of resting land in the rotations, especially in that with cotton; and (*f*) the habits of 'harīq' grasses and methods of establishing them to obtain quickly a cover suitable for burning.

EQUATORIA

In Equatoria Province there are two main centres for experiments, both situated west of the Nile. Kagelu has been the experimental farm for plantation crops for many years, and Maridi has been used chiefly for trials with field crops. East of the Nile, experimental work has been concerned mostly with trials of cotton varieties, conducted by the Plant Breeding Section in various districts, on native-owned land.

Kagelu

History. The Kagelu Farm, situated near Yei on the road from Juba to the Belgian Congo, was, until 1910, included in the Lado Enclave under Belgian administration. It was used to grow food in quantity for the army.

During that time the first ceara rubber (*Manihot glaziovii* Muell. Arg.) was planted, but it was not utilized on any scale until 1916, after the Lado Enclave had been incorporated in the Sudan, and when prices were high because of the war. Then A. A. Bisset and T. Cartwright extended the area of rubber to 340 feddans, but when the price of rubber fell the tapping was discontinued. Cartwright also introduced to the area numerous plants including cinchona, cocoa, sugar-cane, coco-nut, coffee, cam-

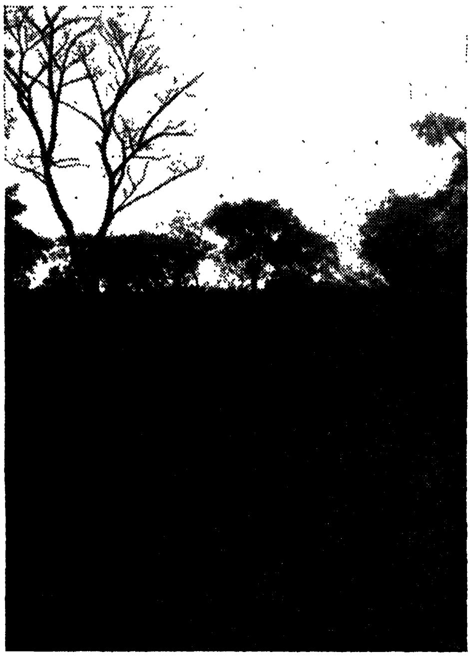

FIG. 176. A crop of ground-nuts at Kagelu, Equatoria Province. In the right background is a termite nest covered, for protection against erosion, with debris cleared from the woodland—a regular practice because of the food value of termites to human beings (*photo F. Crowther*).

phor, tobacco, soya bean, and upland rice. Cassava, sweet potatoes, and dura were also widely grown on the farm for food. Teak was introduced about 1919.

In 1925–6 the plantations were renovated by L. E. Humphreys who laid out coffee nurseries, and these were extended in 1930 when G. R. Davis was appointed coffee officer. The bushes now growing at Kagelu mostly date from his time, but his work was stopped in 1931 as an economy. To safeguard the property against fire, a Senior Forest Ranger, Omer Eff. Hamdi, was posted there, and, while the farm officially was closed, he, in conjunction with Major Logan Gray, the District Commissioner at Yei, made a nursery of forest and fruit trees and extended the plantations of citrus, teak, eucalyptus, cedrela, and oil-palm. In 1937, when agricultural work was resumed, J. G. Myers and, from 1939, H. Ferguson made

Kagelu the centre for their work on plant-introduction. Ferguson also used the farm as a training-ground for native agricultural staff for the entire province. An additional area of 50 feddans for experiments and demonstrations on field crops was obtained by clearing some of the surrounding woodland.

Meteorological Data. The amount and distribution of rainfall at Kagelu, Maridi, Yambio, and Juba are given below, together with the records of temperature and humidity for Juba.

*Rainfall (mm.)**

	Kagelu (Yei) (lat. 04° 07′ N.; long. 30° 40′ E.; alt. 2,720 ft.)	*Maridi (lat. 04° 55′ N.; long. 29° 30′ E.; alt. 2,460 ft.)*	*Yambio (lat. 04° 27′ N.; long. 28° 24′ E.; alt. 2,375 ft.)*
January	9	11	15
February	36	32	32
March	72	64	97
April	162	174	154
May	197	195	177
June	158	171	161
July	168	182	169
August	190	183	174
September	166	147	162
October	168	142	177
November	82	68	74
December	24	18	21
TOTAL	1,432	1,387	1,413
Years averaged	1914–42	1918–42	1918–42

Juba (lat. 04° 51′ N.; long. 31° 37′ E.; alt. 1,485 ft.)

	Daily max. temp. (° F.)	*Daily min. temp. (° F.)*	*Relative humidity 8 a.m. (percentage)*	*Rainfall (mm.)*
January	99·3	68·4	54	3·6
February	99·9	70·7	56	14·0
March	98·8	71·6	65	34·9
April	96·1	71·6	75	116·5
May	92·3	70·5	82	145·5
June	90·5	68·9	83	134·9
July	88·0	67·8	87	122·4
August	88·3	67·8	88	130·7
September	91·0	68·0	83	105·2
October	93·6	68·4	80	90·5
November	95·9	67·8	75	38·0
December	97·5	67·6	64	15·6
Mean	94·3	69·1	74	Total 951·8
Years averaged	1925–40	1925–40	1925–40	1924–42

* 1 in. = 25·4 mm.

The rainfall at these stations (excepting Juba) is about double that of the farms in the Nuba mountains and more than treble that of Wad

Medani. The rain is spread over a much longer period; usually some rain falls every month, whereas Kadugli has two completely rainless months and Wad Medani four. The absence of a very dry period materially alters the cropping, but a dry spell from November to February can be harmful at Kagelu. Temperatures are never as high in summer, nor as low in winter, as in the northern Sudan, and seasonal differences are only moderate. The temperature and humidity data for Juba do not reflect conditions at Kagelu or farther west, but they are the best available.

Soil. The soil at Kagelu is a grey sandy loam overlying ironstone and varying in depth from a few inches to 2 ft. It is very variable, the soils differing widely within a small area of the farm.

Crops and Cultivation. In 1944 the Kagelu Farm of 835 feddans comprised 85 feddans of natural woodland; 490 of timber; 170 of ceara rubber; 15 each of citrus, coffee, and oil-palm; 35 of nurseries and miscellaneous crops including banana, pine-apple, paw-paw, mango, guava, and sugar-cane; and 40 of annual field crops.

The rubber trees after 20 years of neglect again received attention and in 1942 and 1943 were tapped as a war measure, yielding 4½ tons each year, the cost of production per rotl being 1*s.* 5*d.* in 1942 and 1*s.* 10*d.* in 1943. The nurseries are used for the propagation and distribution of successful introductions, as well as for experimental work on the improvement of citrus and mangoes, and investigation of the methods of budding best suited to the humid conditions.

The area under annual crops is at present laid out on the following basic rotation, which, while incorporating the best aspects of native practice, can be changed as experience is acquired:

1st year (after resting under grass). 1st half, beans sown in roughly cultivated grass; 2nd half, dura mixed with 'telebun' (*Eleusine coracana* Gaertn.).

2nd year. 1st half, maize; 2nd half, sesame.

3rd year. 1st half, ground-nuts; 2nd half, sweet potatoes interplanted with cassava.

4th year. Cassava, partly left as a food reserve for later years.

5th, 6th, 7th, and 8th years. Land under grass, aided by a cover crop sown in the fourth year amongst the cassava.

To improve the varieties grown, seed is kept only from the best plants, and the crops are regularly rogued to remove atypical plants.

Cultivation is usually done by hand-tool, and in consequence the soil is not disturbed deeply. Because the dominant grass is *Imperata cylindrica* Beauv. (spear grass, cf. lalang of the East) the main digging of the weeds is a very heavy operation, and takes place therefore only after the ground has been softened by the first showers in April. Cotton is sown on the flat with the local sowing-stick, at a spacing of 75 cm. by 75 cm. (0·56 sq. m.), each cluster of plants being thinned later to 2 or 3. Maize and ground-nuts are sown similarly, but the spacing of ground-nuts depends on the variety (v. Fig. 177 for method of sowing ground-nuts, and Fig. 176 for a growing crop). After sowing, the crops are usually weeded once or twice, the soil left as rough as possible, with the weeds remaining

on the surface to reduce erosion. For coffee, mulching with grass is the general practice, and in the areas of citrus and other fruit-trees the land is divided by earth-banks to reduce erosion of the soil and to assist in conserving rain-water for the dry season. Among plantation crops *Imperata* is successfully suppressed by mulching, and it is never troublesome where teak is grown.

The stock at the farm is limited to three plough-bulls which are being used to test the value of ploughing. No other animals are kept, since Kagelu serves an area where, because of tsetse fly, agriculture has to be maintained without the help of live stock.

Maridi

Cotton does not grow as well at Kagelu as farther west, and in recent years Maridi has become the centre for experiments on it and other established field crops. This work was conducted by the following Inspectors of Agriculture, G. F. March, R. S. Sullivan, A. P. Milne, and A. G. McCall. Experimental work started in 1928 on a small scale and gradually increased, until the area of experiments on the original farm was about 30 feddans in 1941. As a result of erosion and the use of much of the surface soil for constructing anti-erosion banks, the land proved no longer convenient for field experiments. In 1942, therefore, the experiments were moved 2 miles farther west to land previously used as an aerodrome, and more representative of the area the farm was intended to serve. From the outset adequate earth-banks were prepared to check erosion and, except that there are patches where termite nests have been levelled, this land is generally uniform.

Soil. The soil at both farms is a deep-red tropical loam, formed under warm and relatively humid conditions with good drainage. It is more uniform and of greater depth than at Kagelu and contains more organic matter. There are no stones or gravel. Soil samples from the old farm were analysed by the Soil Research Section, the following data being averaged from 11 holes:

Depth (ft.)	*Amount of clay plus silt (percentage)*	*Reaction (pH)*
1	31	6·5
2	49	6·1
3	52	5·9
4	53	6·0
5	56	6·0
6	59	6·1

In contrast to the soils of all government farms outside Equatoria Province those of Maridi are moderately acid.

Crops. The rotation of crops differs slightly from that described for Kagelu, and is as follows:

1st year. Ground-nuts followed by 'telebun'.
2nd year. Ground-nuts intersown with cotton.
3rd year. Maize followed by sesame.
4th year. Sweet potato followed by cassava.

5th year. Cassava continued, the land then resting under elephant grass (*Pennisetum purpureum* Schum.).

6th, 7th, and 8th years. Elephant grass.

In addition to the variety trials with cotton which have been made annually since 1928 in conjunction with the Plant Breeding Section, the experimental work at Maridi has included comparison of rotations,

FIG. 177. Sowing ground-nuts at Opari, Equatoria Province (*photo F. Crowther*).

sowing-dates of cotton, and the inter-cropping of cotton with ground-nuts. Unfortunately the rotation experiment has suffered by the interruption caused by the change in site. Variety trials have also been conducted with numerous other crops including dura, ground-nuts, soya bean, maize, sesame, and rice.

Other Experimental Areas

There is no permanent experimental farm east of the Nile, but since 1928, cotton variety trials have been made at several places including Opari, Kerippi, and Luluba, all near the road from Juba to Nimule. The current practice in these experiments is to sow the cotton in May or June, according to the rainfall, on the flat between anti-erosion banks in lines 85 cm. apart, with 60 cm. between holes. The plants are thinned to 3 per hole. The rotation has been: one year under cotton, followed by two or more years under a cover of natural vegetation, mostly grasses.

Chapter XX

A REVIEW OF EXPERIMENTAL WORK

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INTRODUCTION

EXPERIMENTS in the form of crop introductions must have been in progress in the Sudan for centuries, for numerous established crops, such as cassava, maize, ground-nuts, and sweet potatoes are not of African origin. Although organized research work was not attempted before the present century, it is recorded that Mumtaz Pasha tried cotton at Tokar about 1870. The first experimental farm was started by J. Nevile at Shendi in 1902, to explore the possibility of growing cotton in the northern Sudan by irrigation from the Nile, with special attention to sowing-date and variety. For the same purpose a second farm was opened south of Khartoum at Kamlin in 1903, and shortly afterwards others too were opened in the southern Sudan at Rumbek, Tonj, and Wau, primarily to test cotton as a rain crop, though ceara rubber, and at Wau rice also, were grown. These trials, usually the outcome of individual initiative, were largely exploratory.

The organized scientific approach dates from about the same time, for in 1903 the Wellcome Research Laboratories were opened at Khartoum under the directorship of Dr., later Sir Andrew, Balfour. The first chemist, W. Beam, was appointed in 1904, and the first entomologist, H. H. King, in 1905. The laboratories were concerned mainly with medical work, but numerous agricultural problems also claimed attention. For instance, the entomologist studied crop pests, especially locusts, and the chemist worked on soils, the composition of cereals, and the production of gum arabic. The first botanist, R. E. Massey, was appointed in 1911, and with his transfer in 1912 to the Central Research Farm at Shambat, where E. R. Sawer was Principal, detailed experimental work in the field, concerned especially with cotton, got under way.

Proposals to try irrigated cotton in the Gezira resulted in the installation of the Taiyiba pump in 1911 for trials under commercial conditions. This introduction of irrigation and a new crop to an area which had previously grown only rain crops of dura created a vast range of new problems of soil management, crop production, and control of pests and diseases. For the investigation of these the Gezira Research Farm at Wad Medani was opened in 1918, and from that time the Gezira Scheme, in itself only a very small part of the whole country, has claimed the first

[1] Although the writer accepts responsibility for the selection of material for this chapter and for the method of its presentation, he would like to record his thanks to the following for suggestions and for amendments to his original draft: F. W. Andrews, R. R. Anson, H. W. B. Barlow, H. W. Bedford, W. P. L. Cameron, T. W. Clouston, J. W. Cowland, S. H. Evelyn, H. Ferguson, A. Gaitskell, H. Greene, H. E. King, R. L. Knight, G. F. March, W. A. Porter, W. Ruttledge, and O. W. Snow.

attention of the research workers. There has never been any question of their merely selecting interesting problems for academic study, for the Gezira Scheme has always bristled with problems whose urgency has largely determined the nature and programme of the agricultural research work. With the exception of control of locusts and some early work on American cotton, hitherto little research has been possible on other areas and other crops. Yet dura was never entirely neglected; and now that the Scheme is safely launched and the most urgent of the cotton problems have been resolved, plans are afoot for considerable expansion of work on food crops.

This emphasis on Egyptian cotton throughout the work has been unavoidable because of the extent to which the country has depended upon that crop for its economic development. The Sudan is almost exclusively an agricultural country, and the contribution of cotton to the agricultural exports is illustrated in the following tables giving the averages for the five years 1935–9, prepared by O. W. Snow.[1]

Relative money value of agricultural exports (percentage)

Cotton lint	62
Gum arabic	12
Cotton seed	6
Dura	4
Sesame	3½
All other crops	12½

Relative value of cotton crop from different areas (percentage)

Gezira	75·8
Nuba Mountains	6·3
Tokar	5·8
Gash	5·4
White Nile Province	3·0
Northern Province	2·4
Upper Nile Province	0·2
Equatoria Province	0·9

Relative value of types of cotton (percentage)

Egyptian	90
American	10

Relative value of methods of cotton cultivation (percentage)

Irrigated	81
Flood	11
Rain	7

Of the total agricultural exports 68 per cent., in terms of money value, are cotton lint and seed. Gum arabic being a forest product, the next agricultural crop to cotton is dura, and this constitutes only 4 per cent. of the total. Three-quarters of the cotton exported comes from the Gezira, and this region, with Tokar and the Gash, produces the Egyptian cotton that constitutes 90 per cent. of the whole crop. Only 7 per cent. of the Sudan cotton is grown on rain, and this is all of American type. Economically, therefore, there is every justification for the concentration of agricultural research work primarily on the irrigated cotton crop.

The experimental work has received much attention and assistance from people and authorities outside the Sudan. Since 1924 the Empire Cotton Growing Corporation has supplied senior officers, mostly plant breeders. The London Advisory Committee on Agricultural Research in the Sudan, whose technical members until recently were Sir Edwin Butler, C.M.G., C.I.E., F.R.S., Sir Frank Engledow, C.M.G., and Dr. E. M.

[1] v. Programme of Agricultural Research for the Sudan for 1943–4.

Crowther, has reviewed the work regularly and criticized constructively year by year the programme of experiments. Sir John Russell, F.R.S., and Dr. Martin Leake in 1924 and Sir John Farmer, F.R.S., in 1930 drew up valuable reports and suggestions for the development and extension of the work. Dr. E. M. Crowther of Rothamsted in 1925–6, and Professor F. G. Gregory, F.R.S., of the Imperial College of Science and Technology in 1928–9, both worked for several months at the Gezira Research Farm, the former advising on field experimentation, the latter on plant physiology. Through these outside contacts, and by the facilities granted for annual leave, the research staff have been enabled to keep abreast of the latest developments; for instance, the method of experimental layout evolved at Rothamsted by Professor R. A. Fisher was introduced at the Gezira Research Farm in 1926, the year of its general adoption on the Rothamsted Farm.

A complete account of the experimental work is impossible in a single chapter, and the investigations described hereafter have been selected for their practical bias. This has meant the exclusion of much valuable work, particularly that done in the laboratory, and of all classifications of soils, plants, and insects, although these have necessarily absorbed much time and labour. Only a few of the pests and diseases are described. The procedure usually adopted is to state the problem, recount the method of tackling it, report success or failure at the different stages and, finally, attempt to assess how far the problem has been solved and what remains to be done. Certain key experiments are described at length at the expense of much other work on the same subject, and investigators are named, not for scientific achievement, but only in so far as their work concerns the subjects treated in this chapter. References to published accounts are given only when they concern workers outside the Sudan. For the publications of those within the Sudan details of papers and reports can be found in the appendix, where they are grouped as far as possible under headings corresponding to those of the present chapter.[1]

I. SOIL RESEARCH

Without proper management of the soil no permanently satisfactory system of agriculture can be evolved. Where in the semi-arid regions of the northern Sudan crops have been grown on rain for centuries, usually few drastic changes have been intruded and tradition has furnished an adequate guide to soil management. But when in these regions such innovations as artificial irrigation are put into practice, whole series of new problems arise and there exists no fund of accumulated experience to guide in their solution. A thorough examination of the soil of the irrigated area becomes essential, and the examination must be continuous if any changes leading to soil deterioration are to be detected in good time.

The fundamental importance of research on the soils of the Sudan was early realized by scientific workers, for from 1904 laboratory examinations of soil held a prominent place in the work of W. Beam. Later, when it

[1] The meanings of Arabic units of area, weight, volume, and money given in this chapter will be found in the glossary.—*Editor.*

was proposed for part of the Gezira that the rain cultivation should be superseded by artificial irrigation, he started systematic soil examinations, adapting his methods of analysis to the arid soil; and in 1911 he produced a preliminary report on Gezira soils. This report, a model of its kind, gave detailed results from samples taken at regular intervals along five east-to-west sections of the area. They revealed a large amount of clay, a high proportion of water-soluble salts, adequate supplies of potash and phosphate, but a marked deficiency in organic matter and nitrogen, to remedy which deficiency Beam recommended the inclusion of a leguminous crop in the rotation. His findings have been confirmed by subsequent work.

Laboratory investigations were somewhat interrupted between 1914 and 1919, at which latter date A. F. Joseph took charge. Much of the work carried out by Joseph and his collaborators, especially that of H. B. Oakley, is of fundamental importance in the study of tropical soils but is too specialized to be treated in this review. It was largely concerned with the theory of the constitution of soil colloids and the discovery of suitable methods on soil analysis. Much of it has helped greatly in the interpretation of data on salt extracts, basic exchange, and the swelling of clay soils, but in the present chapter the description of investigations is confined to those soil problems which bear immediately upon the agriculture of the Gezira. These are considered under the following headings: (*a*) Properties of the Soil, (*b*) Penetration and Availability of Water, (*c*) Water-soluble Salts as an Index of Fertility, (*d*) Experiments on Soil Improvement, and (*e*) Nitrogen Supply for Crops.

Properties of the Soil

It is exceptional to find the soil of an irrigated area so heavy and at the same time so alkaline as that of the Gezira; for example, the soils of Egypt are less alkaline, and those of the great irrigation projects in India, in the Punjab and Sind, are much lighter. Hence the Gezira has soil problems peculiar to itself.

The description of the soil given in Chapter VIII is amplified in Fig. 178, prepared by H. Greene, which represents diagrammatically a 6-ft. section of the soil from the surface downwards. Although the soil is completely free from stone, it contains hard black nodules consisting of calcium carbonate blackened by a trace of manganese oxide, and shell fragments.

The following table gives some laboratory data of the soil at the Gezira Research Farm, Wad Medani:

Depth (inches)	*Clay (percentage)*	*Salts easily soluble (percentage)*	*Gypsum crystals over 1 mm. (percentage)*	*Alkalinity (pH)*
0–12	59	0·08	0	9·5
12–24	60	0·10	0	9·6
{24–30	{60	{0·16	{0	{9·5
{30–36	{60	{0·43	{0·3	{9·1
36–48	62	0·46	0·3	9·0
48–60	59	0·60	1·2	8·9
60–72	57	0·63	1·1	8·8

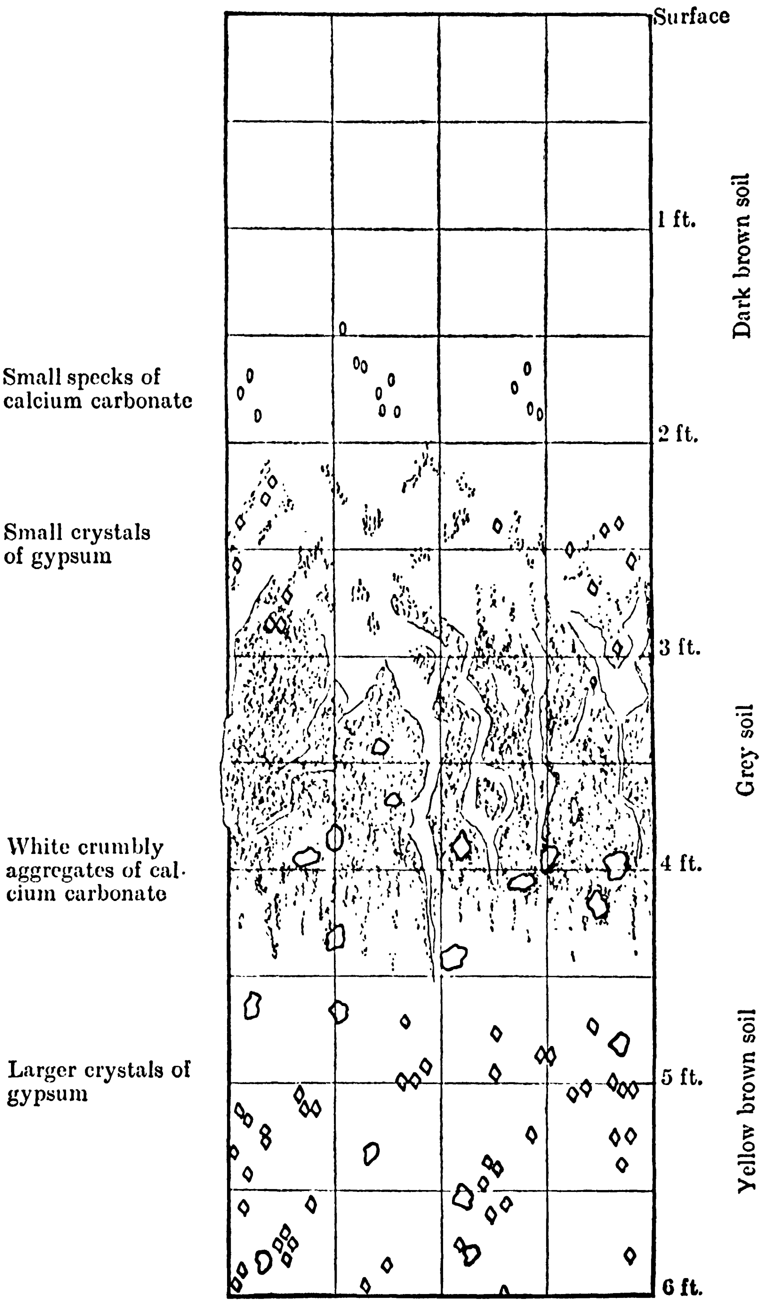


FIG. 178. Diagrammatic representation of the soil profile at the Gezira Research Farm (H. Greene, *J. Agr. Sci.*).

The clay-content is high and does not show much change to a depth of 6 ft. The easily soluble salts are low in the top 2 ft. and consist mainly of sodium carbonate and bicarbonate. Below that depth they increase sharply in amount and consist mainly of sodium sulphate accompanied by the less soluble gypsum, a hydrated form of calcium sulphate. The values for gypsum in the above table are only for those crystals retained by a 1-mm. sieve, the actual percentage of gypsum, including crystals of all sizes, being greater. Values for soil alkalinity of around 9·0 on the pH scale show the soil to be extremely alkaline; and the alkalinity is greatest in the first and second feet from the surface.

In some parts of the irrigated Gezira the salts are greater in amount than shown in the preceding table and lie nearer the surface, whereas in others they are less in amount and lie at a greater depth. It has been found that, in general, the less salty the soil the greater the penetration of both rain and irrigation water and the development of plant roots.

Penetration and Availability of Water

Whether crops are grown by irrigation or by rainfall, the nature of the soil profoundly affects the amount of moisture available to their roots; and the amount of available soil-water becomes even more important when great loss of water is sustained by both crops and soil, as in the hot, dry climate of the northern Sudan.

The canalization of the Gezira Scheme enabled large quantities of water to be applied to soil which had previously received annually an average of from 200 to 450 mm. (8 to 18 in.) of rain according to the district. Under rain cultivation, which still persists outside the boundaries of the irrigated area, small earth banks ('terūs') are constructed to conserve rain-water on selected areas where soil has received no preliminary cultivation and, except in the rainy season, has been extensively cracked by drying. In districts whose rainfall is comparable with that of the irrigated area the only crop grown is dura, sown usually in the latter half of July after the rains have broken. The heaviest rain falls in late July and early August. The land is kept clear of weeds, and the dura grows rapidly and is harvested in early November. The changes in the moisture-content of the soil occurring during this sequence are shown in Fig. 179, prepared by Greene. When the rains break, at first there is considerable increase only in the first foot, whereas with further storms the penetration extends down to the third foot, but not below. In succeeding months the moisture-content gradually returns to that characteristic of the dry season. In Fig. 179 the salt-content of the soil is also included, and it shows the same sharp rise in salts in the third foot as already described for irrigated soil. It will be noted that the rain penetrates as far as, but not through, the layer in which there is the rapid increase in salts.

The amount of water applied to the land in a single irrigation is about 400 m³. per feddan, the equivalent of about 95 mm.[1] of rainfall. Thus the fourteen irrigations which the cotton crop usually receives supply about four times as much water as the average year's rainfall of the central

[1] 1 in. = 25·4 mm.

Gezira irrigated area. The penetration of a single irrigation into a representative Gezira soil is illustrated in Fig. 180, which shows the moisture-content of the soil down to 6 ft., before and after a normal irrigation of cotton. Twenty-four hours after the application of the water less than a quarter of the total amount had penetrated below the first foot.

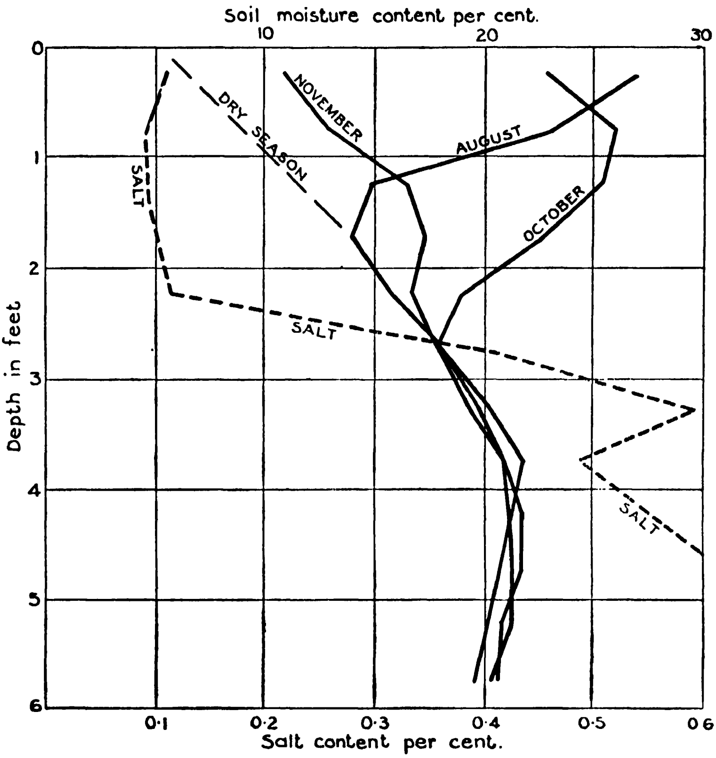


FIG. 179. Moisture-content and salt-content of land under rain cultivation (H. Greene, *J. Agr. Sci.*)

Owing to the high clay-content of the soil, water enters very slowly and only a fraction of the water in the soil is available to plants, since the roots are unable to absorb moisture when the moisture-content of the soil falls below about 20 per cent. This is shown by the following values, determined by Greene, as a rough guide to the interpretation of field data on soil-moisture:

	Soil moisture-content (as percentage of dry weight)
Maximum for healthy growth . . .	Over 40
Optimum for growth	36 to 40
Cotton begins to need water at . .	About 30
Cotton suffers a severe check, crop ruined at	23 to 24
Wilting point for cotton seedlings in pots .	18 to 20

Thus it appears that for the optimum growth of cotton there should be a water-content of at least 30 per cent. to a depth of several feet. That

this optimum is far from realized is clear from Fig. 180, for the required supply is approached only in the top foot, and even there falls much below optimum just before an irrigation. The Gezira crop is evidently sustained on a very narrow margin of water supply, especially below the top foot of soil.

With prolonged irrigation of this soil small quantities of water gradually penetrate to greater depths, but, although T. W. Clouston has shown that some cotton roots are found as far down as 5 ft., the greatest lateral root development of cotton is at a depth of only 1 ft. Because of the low permeability of the soil, little or no water applied at the soil surface reaches the water-table, which is found at a depth of about 50 ft. This immediately differentiates the soil and crops of the Gezira from those of the Egyptian Delta, where the soil is highly permeable and where the water-table is often within 3 ft. of, and rarely more than 6 ft. from, the surface, the precise level varying with movement of the Nile and of water in neighbouring canals. Hence root penetration is checked in the Sudan Gezira by drought and in the Egyptian Delta by excess water. Where these extremes are not encountered, as in the Gash Delta and in parts of India, cotton roots may penetrate to considerable depths, to at least 18 ft. in the Punjab.

That the high clay-content of Gezira soil is not the sole cause of its low permeability to water is seen by comparing it with the soil of the Gash Delta. H. Greene and O. W. Snow give the following data for soil properties:

	Gezira	*Gash Delta*
Clay (per cent. in soil)	50 to 60	40 to 70
Exchangeable sodium (per cent. of total exchangeable bases)	8 to 12	About 2
Permeability to water	Bad	Good
Root development	Poor	Good
Linear shrinkage per cent. (Vageler)	About 15	About 5
Water-soluble salts (per cent.)	0·1 to 1·0	Below 0·1
Alkalinity of aqueous extract (pH)	About 9	About 8

Some of the soils of the Gash Delta contain even more clay than those of the Gezira, but the clay in the Gash is associated with much less 'exchangeable' sodium. Here reference must be made to the phenomenon of base exchange in soils. The structure and other properties of clay soil are strongly influenced by the nature and amount of the bases which are loosely combined with the clay fraction in such a way as to be replaceable by other bases. In most clay soils the dominant exchangeable base is calcium; such soils tend to be of good structure, the clay particles being well aggregated and thus allowing easy water-movement. Where some of the exchangeable calcium is replaced by sodium the clay particles tend to disperse, and the soil deteriorates in structure and becomes less permeable to water. The Gash soil, by comparison with that of the Gezira, has very little exchangeable sodium and is therefore greatly superior in structure and permeability to water.

This greater permeability to water of the Gash soil is well illustrated

in the different method of cotton-growing practised there. The seed is sown after a single heavy flooding lasting 2 or 3 weeks, followed by no further irrigation and by only about 4 in. of rainfall throughout the growth of the crop. The soil is so permeable that water is stored to a considerable depth, and, as the roots grow downwards, they tap layer after layer of the moist soil.

Although in the Gezira, as mentioned earlier, the more salty the soil the less the root development, the primary cause of this inhibition of root

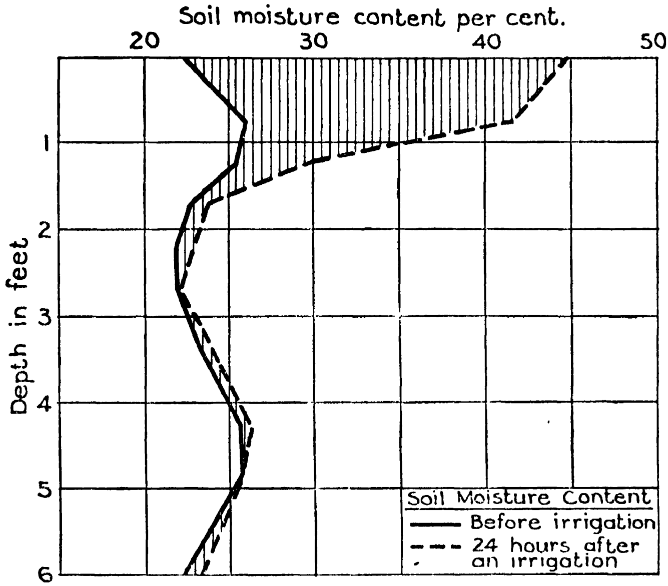


FIG. 180. Moisture-content of a cotton plot at the Gezira Research Farm 24 hours before, and 24 hours after, a watering estimated at 420 m³. per feddan.

growth by salt concentration is evidently not toxicity, but rather the resulting impermeability which causes drought. When Greene opened up Gezira soil by digging to a depth of 3 ft., returning the soil layer by layer, water penetration was notably increased and the cotton roots developed extensively to a much greater depth.

WATER-SOLUBLE SALTS AS AN INDEX OF FERTILITY

Prolonged study of the relation between soil fertility, as expressed by the yield of cotton, and the amount of water-soluble salts has shown that the association of low salt-content with high yield, and the reverse association, have been sufficiently close to render salt-content a valuable guide in selecting land for inclusion in irrigation schemes. By 1930 the whole of the Gezira plain likely to be used for irrigation had been included in a soil survey, and maps had been prepared showing the distribution of clay and of water-soluble salts. The samples were collected methodically at every minute or two minutes of latitude and longitude, and the results of the salt analyses are given in Fig. 181, the

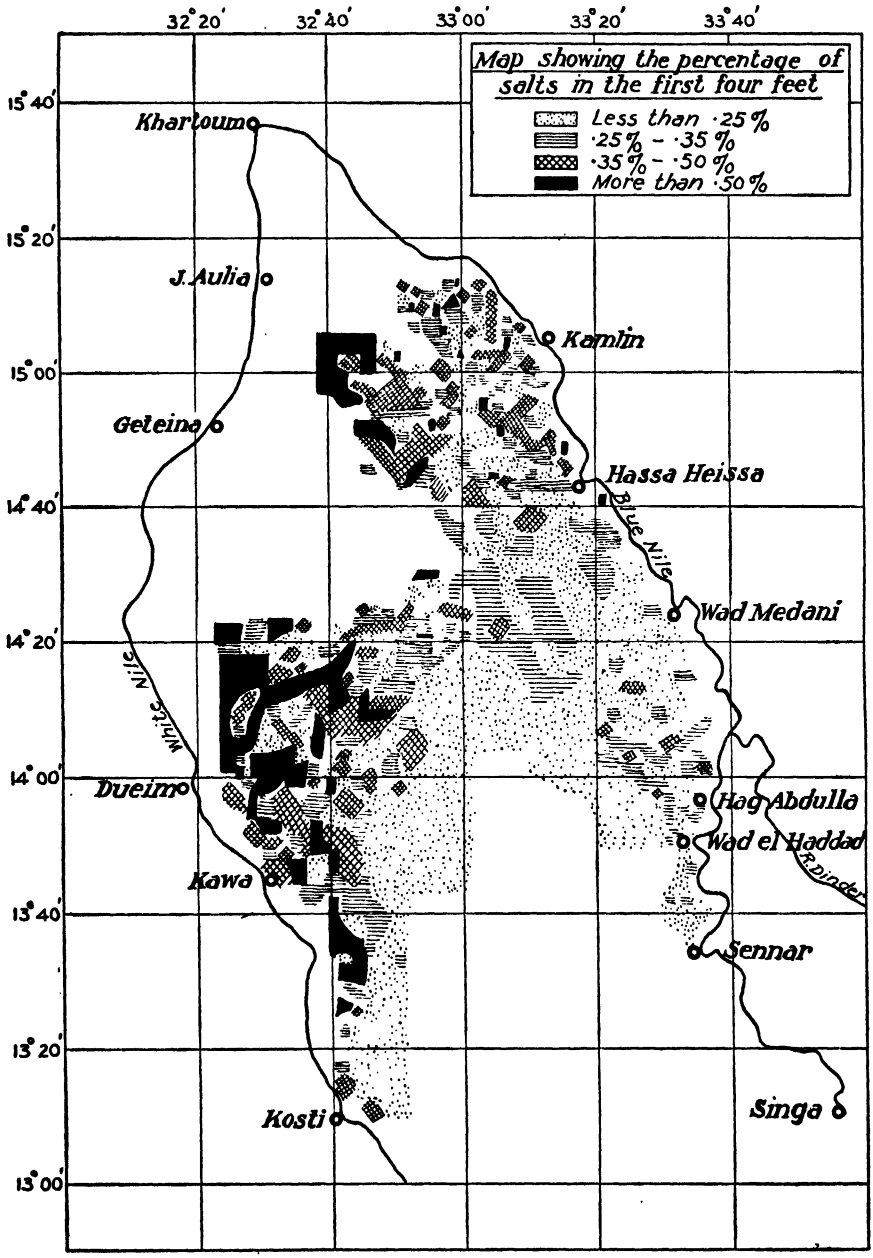


FIG. 181. Map of the Gezira showing the percentage of easily soluble salts in the top four feet of soil (A. F. Joseph and B. W. Whitfield, *S. G. Report.*)

shading showing the degree of salt concentration. The saltier soils occur in districts of lower rainfall to the north and west of the irrigated area, the less salty soils mainly towards the south, on higher ground and where the rainfall is heavier. This map has already been utilized successfully as a guide in extensions of irrigation in the Gezira Scheme.

Later work has shown that the use of salts as an index of soil fertility has been successful in the surroundings of the Gezira Scheme mainly because there the clay-content is reasonably uniform and the relative composition of salts constant. It is, however, of less value in other parts of the Northern Sudan where these two factors are more variable; and recently Snow, as a result of his studies particularly of the soils and cotton yields at the Dueim pump-scheme on the White Nile, has introduced the *Sodium Value* test as more generally applicable.

As already described, in a clay soil containing a high content of sodium in a replaceable form the soil structure has deteriorated and the permeability to water greatly reduced. Snow therefore standardized a measure whereby the total soluble plus exchangeable sodium, in samples representative of the top 3 ft. of soil, is determined in the laboratory and the result expressed as the amount of sodium per unit of clay (milligram equivalents of sodium per 100 grammes of clay). He obtained values as low as 1 for new riverain soil-deposits of excellent quality and as high as 100 for black-alkali soils, where deterioration is advanced. Good soils of the Gezira Scheme gave values around 10. Using this sodium value as a yard-stick for advisory purposes, Snow suggested for example, that, under the rotation of crops practised at Dueim, economic cotton yields could be expected where the value was below about 25.

Subsequently many other areas were examined, including the White Nile pump-schemes of Hashaba, Um Gerr, and Wad Nimr, and the Kerma basin in the Northern Province. The sodium value estimates of fertility proved close to those obtained by the method of visual examination of soil-pits in the field, developed by J. D. Tothill; and since these estimates were largely confirmed by the subsequent growth of crops on those sites selected for irrigation, the sodium value test has been adopted as a routine laboratory examination of the soils of all areas of the Sudan proposed for irrigation. Since the information can be obtained ahead of new irrigation projects, no financial loss need in future be incurred by the irrigation of unsuitable land.

Experiments in Soil Improvement

At one time it was feared in some quarters that the artificial irrigation of such a salty alkaline soil as that of the Gezira Scheme might be followed by a rapid deterioration in its fertility, for there have been numerous instances in other countries where, through salt accumulation in the upper soil-layers, land has gone out of cultivation after a few years of irrigation. Fortunately the irrigation water applied in the Gezira is of good quality, i.e. a high ratio of calcium to sodium and a low content of total salts, and careful investigations have proved that there is no risk of early or rapid deterioration.

R. E. Massey described experiments conducted at Shambat in 1913–14 in which no appreciable upward movement of salts was found. H. Greene and R. H. K. Peto, in more elaborate experiments of the same kind made in the Gezira, found that the small apparent movements occurring under normal irrigation and cultivation arose largely from the swelling and shrinking of the soil mass, occasioned by change in moisture-content and by disturbance from cultivation. Apart from these apparent changes there may be a small downward movement of salt through the soil material at a rate of a ½ in. in 3 years; but there is no upward movement. Their estimate of the amount of salts added during a normal season of irrigation to crops grown on a standard rotation was 1 ton per feddan per 3 years. These salts, deposited near the surface, were gradually washed downwards. When the Continuous Cotton Plot (Plot 4, Fig. 160) was examined after eighteen successive crops it showed no increased alkalinity from the addition of sodium salts in the irrigation water.

Although there is no sign of rapid deterioration, numerous experiments have nevertheless been undertaken to discover practicable methods of improving the soil and of guarding against any slow deterioration. If some of the sodium combined with the clay could be replaced by calcium the permeability would be increased and the soil, presumably, be made more productive.

Addition of Gypsum

Beam as early as 1911 suggested the application of gypsum, a form of calcium sulphate, to combat the effects of the sodium carbonate, but the amounts he suggested later proved inadequate. As experimental work in the Gezira developed, extensive tests with soil-improvers were made by Greene. The results of one experiment carried out in 1927 on soil of especially low permeability are shown diagrammatically in Fig. 182. Soil-moistures to a depth of 6 ft. were measured at various intervals after irrigation, on soils receiving amounts of gypsum varying from 0 to 10 tons per feddan. The land was uncropped and was flooded for 14 successive days in April, starting 1 to 2 weeks after the application of the gypsum. Data collected shortly afterwards showed a remarkable increase in water-penetration where gypsum had been applied. Whereas on untreated soil the moisture-content reached a value of 30 per cent. to a depth of only about 1 ft., with 1 ton of gypsum it reached this value to 1½ ft., with 4 tons to 3 ft., and with 10 tons to 3½ ft. Thus with the application of 10 tons of gypsum it is possible to obtain water-penetration approaching the optimum for cotton described earlier. A second set of data, collected after the land had dried for 6 months, showed that where gypsum had been added the additional moisture had persisted in the lower layers. A second flooding, this time of 10 days' duration, preceded the December sampling, and again marked improvement in water-penetration was obtained where the gypsum had been applied.

Unfortunately the benefit from gypsum applied in moderate amounts appears to be only temporary. Greene and Snow examined the cotton yields from 3 years' experiments involving applications of gypsum and

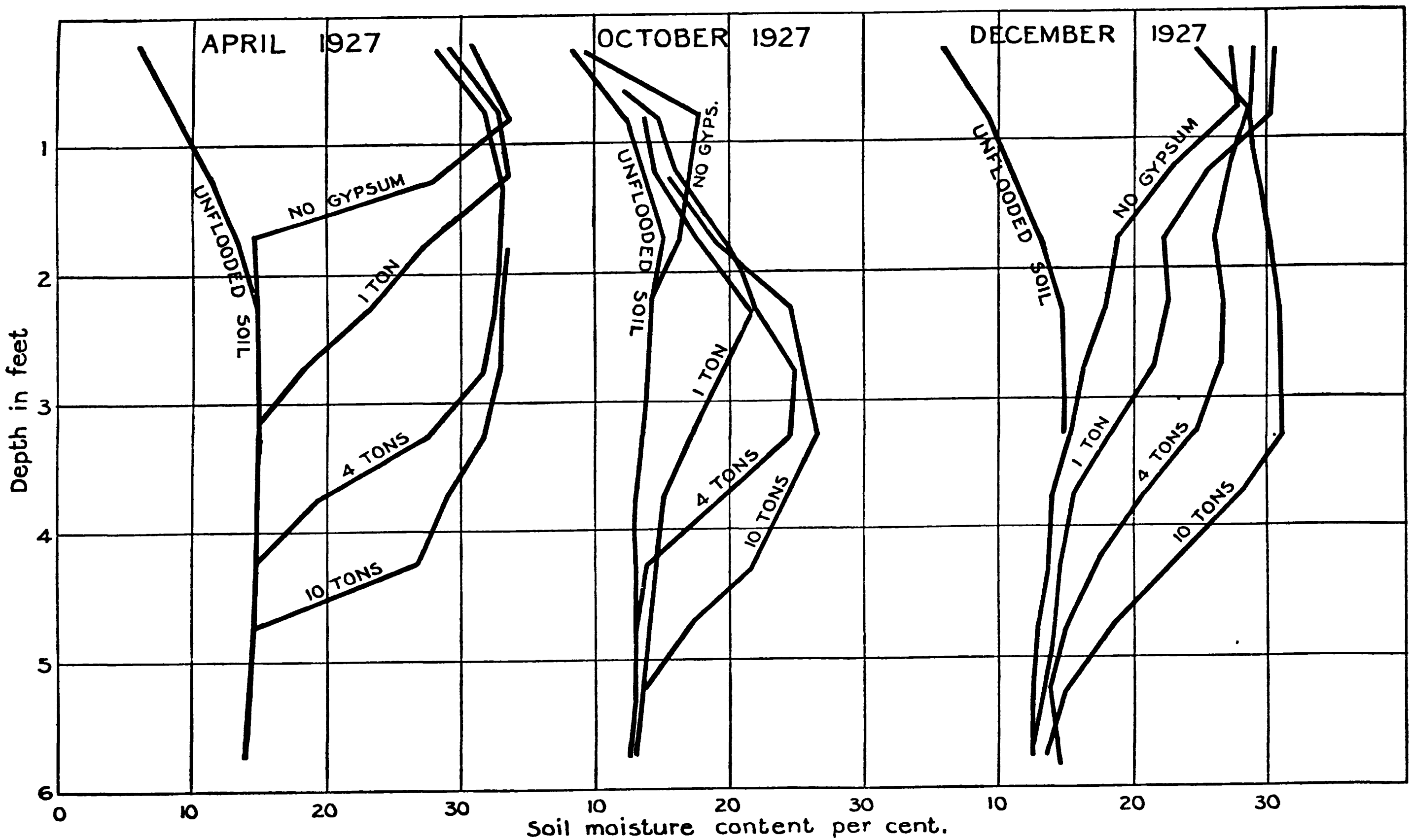


FIG. 182. Effect of gypsum on the permeability to irrigation water of soil at the Gezira Research Farm (H. Greene, *J. Agr. Sci.*).

ammonium sulphate. The average yields of seed-cotton in big kantars[1] per feddan were:

Gypsum	(a) Immediately following the application of gypsum — Ammonium sulphate: Nil	(a) Ammonium sulphate: 200 rotls per feddan	(b) 3 years later — Ammonium sulphate: Nil	(b) Ammonium sulphate: 200 rotls per feddan
Nil . . .	2·60	3·43	2·03	2·51
2 tons per feddan .	3·48	3·94	2·15	2·68
4 tons per feddan .	3·51	3·97	2·17	2·67

In the absence of ammonium sulphate gypsum increased cotton yields by 0·88 kantars for 2 tons, and 0·91 kantars for 4 tons, per feddan; but 3 years later, when the land again came under cotton and received a further application of ammonium sulphate but not of gypsum, the additional yields from residual gypsum ranged only from 0.12 to 0.17 kantars per feddan. Although gypsum can be obtained from the salt works at Port Sudan and deposits are also available for quarrying in the Red Sea Hills, these results with cotton, considered in conjunction with the comparative prices, do not justify the use of gypsum for Gezira crops.

Drainage of the Soil

In some parts of the Gezira Scheme series of surface drains have been dug to facilitate the removal of storm-water which can prove harmful to the cotton crop by killing seedlings, encouraging weeds, and puddling the soil; but there are no drains to receive and remove water after it has percolated through the soil. Such subsoil drains, which appear to need a free water-table and also a permeable soil-layer immediately above the drains, have been of great assistance in Egypt and elsewhere in land reclamation, not only in lowering the water-table but in reducing the concentration of sodium salts. In the Gezira the impermeability of the soil and the restricted lateral movement of water prevent the use of such drains. For reasons of cropping and cultivation, as well as of cost, the drains cannot be closer than about 20 yards, a distance very much greater than can be tapped by lateral movement. How restricted is this lateral movement of water in the Gezira is illustrated in the ease with which the canal banks, without lining or other preparation, can contain water at a level above that of the land or roadway alongside, with little or no seepage.

The desirability of drainage in the Gezira was once given considerable publicity, especially by two German chemists, P. Vageler and F. Alten,[2] and by W. L. Balls,[3] the last named advocating laying special filter-

[1] 1 feddan = 1·038 acres = 0·420 hectare. 1 kantar of cotton = 315 rotls = 312 lbs. = 141·5 kg. 100 rotls = 99·05 lbs. = 44·93 kg.
[2] Vageler, P., and Alten, F. (1932), *Z. Pfl. Ernähr Düng*. A. 23, p. 208.
[3] Balls, W. L. (1935), *Emp. Cott. Gr. Rev.* xii, pp. 32 and 297.

joint tile drains which had been used successfully for land reclamation in Egypt. The argument was advanced at a period of very low cotton yields, which were taken to provide circumstantial evidence that drainage was urgently needed to arrest the rapid soil deterioration assumed to be responsible for the low yields. But there was abundant evidence that neither Vageler and Alten nor Balls were correct in their surmise, and that deterioration, even if occurring, was not rapid, and that no desperate measures were required. On the contrary, the studies in soil management already in progress indicated that a gradual but steady improvement in the Gezira soil was proceeding.

Nevertheless Greene and Snow experimented with various types of drains, but none of them gave results which would justify the enormous cost of digging. In one experiment perforated iron pipes were inserted at a depth of 2 feet without disturbing the upper soil-layer, in a field of which part had been treated with gypsum. The soil was kept continuously under water for 8 weeks and the effluent produced was as follows:

Untreated soil	1·8 m^3. per feddan per day
Soil treated with gypsum	6·2 m^3. " "

Owing to the high rate of evaporation additions of 56 m^3. of water per feddan per day were required to maintain standing water on the surface, but even under this heavy irrigation only small effluents were obtained from untreated, undisturbed soil, though these were increased, at least temporarily, by the application of gypsum.

In another experiment, by means of fluorescein Greene followed the movement of water in relation to the drains and found that no fluorescein entered the drains if applied to untreated soil at a depth of 6 to 21 inches even as near as 1 yard from the drains. Where, however, gypsum had been applied, the recovery of fluorescein indicated lateral movement up to a distance of 2 yards from the drain. Field experiments comparing land with and without drains provided only small effluents in the drains, and showed but little effect of the drains on cotton yields.

The experiments as a whole confirmed the original opinion that no ordinary method of tile drainage would lead to speedy improvement in soil permeability, and this, combined with the high cost of installation per feddan, renders tile drainage impracticable for the Gezira Scheme.

Cropping with Saltbush

Although there is little prospect that crop yields will fail in the near future through lack of drainage, the fact must be faced that every 3 to 4 years about 1 ton of salts is added in the irrigation water to every feddan of the Gezira Scheme. As surplus salt cannot be washed out by drainage, attempts were made to see whether appreciable amounts of sodium might be removed by taking occasional crops of saltbush.

The natural habitat of many species of saltbush (*Atriplex* spp.) is salt-marshes, and it has been found in other countries that, since during growth they absorb large quantities of alkali salts, especially sodium chloride, removal of the tops leads to a reduction in the salt concentration of the soil.

Experiments were started in the Gezira by Greene and Snow in 1935 with an Australian species (*A. muelleri* Benth.). Good growth was obtained with a final yield of 4 tons of dry material per feddan, which upon analysis showed a high sodium-content. Their analyses of saltbush, cotton plants, and irrigation water are summarized as follows:

Constituents of Saltbush, Cotton, Irrigation Water, and Soil (rotls per feddan[1]*)*

	Removed by		*Added by Irrig. water*		*Soluble bases, &c., present in soil and water: cumulative total to a depth of*			
	(a) Saltbush (4-ton crop)	*(b) Cotton (3½-kantar crop)*	*(3,000 tons)*	*(6,000 tons)*	*1 ft.*	*2 ft.*	*3 ft.*	*4 ft.*
Calcium	102	Small	165	330	33,850	63,190	89,490	..
Magnesium	35	Small	36	72	3,250	4,340	6,500	..
Sodium	*584*	*Small*	*68*	*136*	*5,110*	*18,440*	*33,740*	..
Potassium	106	8	14	27	1,740	5,210	7,810	..
Nitrogen	207	63	3	6	1,080	2,090	..	..
Phosphorus(P_2O_5)	43	2	..	..	5,940	..	..	..
Sulphur	45	..	17	32	..	12	1,020	2,140
Chlorine	578	..	17	34	115	285	671	1,690

Two amounts of irrigation are given, the lighter for saltbush and the heavier for cotton.

The table shows clearly the large amount of sodium removed by saltbush as compared with that removed by cotton. Even so, it would take about 35 successive crops of saltbush to reduce the sodium content in the top 3 feet of Gezira soil to half its present value; so saltbush cannot be expected to achieve big changes in soil conditions. But merely as a means of maintaining Gezira soil at its present level of fertility, since the sodium content of saltbush is high compared with that of the irrigation water, a crop of it grown every 12 to 16 years would prevent any progressive accumulation of sodium salts. This crop, however, as the table shows, removes three times as much nitrogen from the soil as a crop of cotton, and therefore would prove exhausting if included in the Gezira rotation. Allowance would have to be made for this by additional periods of rest or by the use of manure.

Nitrogen Supply for Crops

Beam in 1911 stressed the marked deficiency of nitrogen in the soils of the Gezira and other parts of the northern Sudan. Early work at Shambat showed that the amount of nitrogen there was less than one-third of that usual in temperate soils. Beam concluded that successful cultivation in the northern Sudan would largely depend upon making good this deficiency of the soils.

Nitrogen is present in the soil in numerous combined forms, most of which are relatively inert. The form most readily available to crops for absorption by their roots is nitrate, though this form constitutes only a small fraction of the total. Typical analyses of total nitrogen, nitrate, and

[1] 1 rotl per feddan equals 0·95 lb. per acre. In the table the calcium, magnesium, and sodium figures refer to replaceable and water-soluble materials only. The calcium and sulphur in the gypsum are excluded.

of an intermediate form, nitrite, are given for successive 1-foot layers down to 6 feet in the following table of data obtained by Greene:

Nitrogen in Gezira Soil (parts per million in oven-dry soil)

Depth (ft.)	*Nitrite*	*Nitrate*	*Total nitrogen*
1	0·3	5	295
2	0·2	5	240
3	0·3	13	287
4	0·3	35	299
5	0·2	49	269
6	0·3	40	235

Whereas nitrite is present only in traces, the amount of nitrate, which will be shown later to vary considerably, increases with depth. The remaining nitrogen occurs in materials of varying resistance to decomposition, including micro-organisms, plant residues, and products partially decomposed. When all these are grouped together, the total nitrogen in the soil shows no clear-cut trend with increasing depth.

Since nitrate is the main form in which crops absorb their nitrogen supply, it is the one which has received most attention in the Gezira and the only form which will be considered in detail in this review.

Soil Nitrates

Preliminary work by R. E. Massey at Shambat in 1915, and later by F. J. Martin and Massey, on the distribution of nitrate in the field revealed a progressive accumulation of nitrate in cotton ridges during the season, the final amount being many times as great as that present in the furrows between the ridges. They found more nitrate in the top foot of soil than below. Irrigation gave a general increase in the amount of nitrate, but this gradually disappeared as the land dried.

When the chemical work was extended to the Gezira Scheme, Greene decided to follow closely the changes in amount of nitrate in selected plots at the Gezira Research Farm, especially in the rotation experiments. The Three-Course Rotations experiment has been under observation since 1927, the Combined Rotations experiment since 1936. (A description of these experiments and their cotton yields is given in the next section, v. p. 462.) At first the determinations of nitrate were limited to the top foot of soil; but later both the top and second feet were examined not only for nitrate but for moisture-content and soil-structure with which the changes in nitrate might be correlated.

From 16 years' data from the Three-Course Rotations experiment (Plots 10 to 15) the amount of nitrate in the top foot of soil, averaged over the cotton phase, and the yields of cotton were as shown in the table on p. 456.

The highest nitrates occurred in the rotation which gave the highest average yield of cotton, and the average nitrate contents over the year which included the cotton phase are in the same order as the average cotton yields.

The changes in amount of nitrate in the top foot from month to month throughout the year are shown in Fig. 183 for three of the commonest three-course rotations. From these diagrams it is at once clear that methods

of cropping had marked effects on the nitrate values. For the year of the cotton crop, in general, nitrate was high in the early part of the season and low towards the end. In the rotation dura–resting–cotton, as Snow recently pointed out, the nitrates at the time of cotton-sowing were not as high as two months later when a temporary accumulation occurred. He suggested that the decomposition of the dura residues proceeded so slowly that more than one year of rest was necessary to complete it, and nitrate accumulation was, in consequence, delayed. This suggestion links up with results from field experiments, to be described in the next section, where improved yields of crops have followed the flooding and hoeing of resting land.

Nitrates and cotton yields from the three-course rotation experiment. Average of 16 years.

Rotation	Nitrate-nitrogen (parts per million)	Cotton yields (big kantars per feddan)
'Lubia'–resting[1]–cotton .	10·9	4·57
Resting–resting–cotton .	9·0	4·24
Dura–'lubia'–cotton .	8·5	4·06
Dura–resting–cotton .	8·3	4·05
Dura–dura–cotton . .	5·8	3·00

As expected in the case of an exhausting cereal crop, the nitrate in soil under dura was low; but even with a legume which, through its nodule bacteria, adds nitrogen to the soil instead of only taking from it, the nitrate level was also low. Presumably under a 'lubia' crop the nitrogen is stored in the form of protein which is changed to nitrate later; for where a year's rest followed the 'lubia' crop there was a rapid and progressive increase in nitrate (v. Fig. 183), the high values persisting until the cotton was sown. As Greene has stressed from a general review of the nitrate data, resting land which had legume in the previous year contained more nitrate than comparable land previously under dura or cotton, the differences being clearly marked in both the top and second feet of soil. In general, one year's rest was sufficient to raise the nitrate status of the top foot but a second resting season was needed for considerable improvement in the second foot. Where cotton followed a legume without a resting period, as in the rotation dura–'lubia'–cotton, there was insufficient time for the accumulated protein to be changed to nitrate, and this may explain the negligible benefit conferred on the cotton when it is preceded by 'lubia' instead of a resting year (v. table of *Cotton Yields* given above).

The nitrate data in Fig. 183 refer only to the top foot of soil, but though in the second foot the nitrate is, on an average, lower, the differences between crops and rotations, although smaller, tend generally in the same direction. Samples taken at depths greater than 2 ft. frequently revealed high nitrate irrespective of cropping, as for example in the 4th- to 6th-foot layers in the table already given (p. 455). Snow discovered the existence of these high nitrates in 1935. The shallowest depth at which they occurred varied from 3 to 6 ft., according to the type of soil, and the amounts occasionally were as much as ten times as great as in the top foot.

[1] v. pages 6 and 462 for explanation of 'resting land'.

Nitrate-content appeared to be at a minimum in the zone of deepest root-penetration and the accumulations below to be beyond the range of root-absorption. This deep reserve of nitrate suggests that efforts to obtain

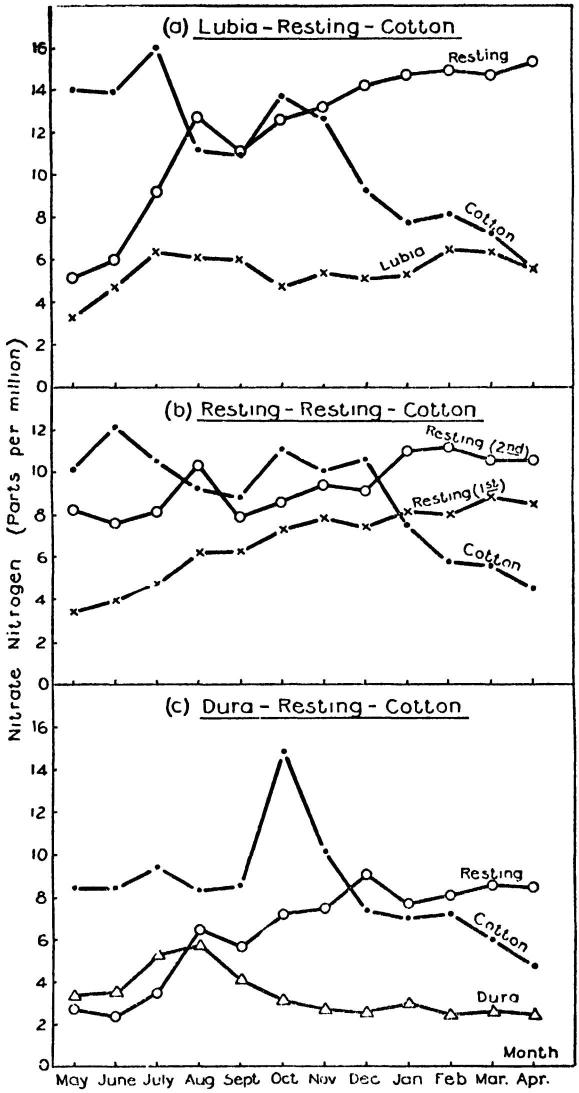


FIG. 183. Soil nitrates in the top foot, expressed as parts nitrate-nitrogen per million of dry soil, for three 3-year rotations. The data are averages of 16 years' results from the Three-Course Rotations experiment (Plots 10–15) at the Gezira Research Farm (H. Greene and O. W. Snow (original)).

improved water-penetration and deeper rooting of crops, by the introduction of new varieties or methods of crop management, may succeed in procuring additional nitrogen for the crops.

It is tempting to speculate whether fluctuations in the cotton yields of

the Gezira from year to year are in some way bound up with the varying utilization of these deep nitrates, but this possibility can be examined only by further intensive field and laboratory tests. Meanwhile the indications from the first and second feet of soil within any single rotation do not support an interpretation of annual variation in cotton yield in terms of the amount of nitrate present in the soil at any stage of the rotation. Snow has recently separated the 16 years' data of cotton yields from the Three-Course Rotations experiment into the 8 best and the 8 worst years. Grouped in this way the yields, together with nitrates for the first foot of soil averaged for the same set of 8 seasons, are as follows:

	Cotton yields (kantars per feddan)		*Nitrates (nitrate-nitrogen, parts per million)*	
Rotation	*Best years*	*Worst years*	*Best years*	*Worst years*
'Lubia'-resting-cotton .	5·97	3·16	9·7	12·1
Resting-resting-cotton .	5·39	3·08	6·1	11·5
Dura-resting-cotton .	5·20	2·89	6·2	10·4

When *rotations* were compared for the average of all seasons, that containing the highest nitrate produced the greatest yield of cotton; but when *seasons* were compared the relationship was different. As seen from the above table, in all the rotations the higher yields tended to be associated with the lower values for nitrate. This suggests that in the poor seasons the cotton plants were unable to absorb nitrate rapidly, and that there was therefore a less rapid exhaustion of the nitrate supply. Thus reasons other than the presence of low nitrate in the top foot of soil must be found to explain seasons of low cotton yields in the Gezira.

In an elucidation of these and other problems the data obtained by Greene on the structure and other physical properties of the soil are particularly valuable. He found that rest tended to improve and irrigation to worsen the structure of the soil. Again, the soils of the Three-Course Rotations were notably better in nitrogen supply and tilth, and lower in alkalinity, than the soils of the Combined Rotations, and correspondingly there were pronounced differences between the two experiments in the average yield from comparable rotations. For example, the resting-resting-cotton rotation in the former experiment gave a yield of 5·04 kantars per feddan when averaged over 10 years, but in the latter yielded only 3·24 kantars per feddan, or 64 per cent. as much, over the same 10 seasons and with the same variety of cotton.

Thus Gezira soil which, from superficial examination in the field, may appear uniform over large areas, is proved by laboratory examination to vary sufficiently within small distances to produce large differences in the yield of crops grown under the same system of soil management.

In one experimental area, in which each cotton crop of a three-year rotation received ammonium sulphate, Greene found higher nitrates and lower alkalinity for the surface soil than in other areas which were not manured. The cumulative residual effect of ammonium sulphate should improve the soil of the Gezira, by contrast with the deterioration which may occur

in acid soils of temperate regions if ammonium sulphate is used repeatedly without lime. Ammonium sulphate necessarily behaves as an acid in the soil because plants or micro-organisms take up ammonia and leave an acid residue. This secondary effect is advantageous in an alkaline soil but not in an acid one.

Soil Micro-organisms

The activity of micro-organisms associated with the nodules on the roots of legumes is everywhere evident from the improved fertility obtained wherever crops of 'lubia', lucerne, ground-nuts, and beans are grown, and this in both the northern and the southern Sudan. Their activity, as already mentioned, is reflected in the high nitrate values following 'lubia' in the 'lubia'–resting–cotton rotation shown in Fig. 183.

Other organisms equally deserving of study in any general investigation of soil-nitrogen are the nitrogen-fixing bacteria which occur freely in the soil, unassociated with the roots of plants. These enable the same piece of land in non-irrigated areas of the Gezira to produce crops of dura year after year—a practice which has continued for centuries without the help of either manure or legume. These crops remove about 14 rotls of nitrogen per feddan in the central Gezira, and after allowing for the nitrogen added in rainfall, there remain about 12 rotls of nitrogen per feddan to be accumulated annually, presumably by the agency of these nitrogen-fixing bacteria.

Examination of moistened Gezira soil under the microscope at once reveals the presence of many *Azotobacter* organisms. Massey drew attention to their presence in 1915, stating that *A. chlorococcum* was widely distributed throughout the Sudan soils. He found this species particularly abundant in light, open soils, but less plentiful in clay soils because of defective aeration. It resisted desiccation to a remarkable degree and was found mainly near the soil surface.

After that early work the subject was not pursued until T. W. Clouston and M. C. Hattersley started in 1936 a systematic examination of the micro-organisms present in Gezira soil, with especial reference to those concerned in the nitrogen-cycle. A. S. Boughey, on his appointment in 1938, took over the investigations, and his results confirmed and extended the earlier findings. The free nitrogen-fixing organisms were largely concentrated in the top foot of soil, rarely being found below 1½ feet from the surface. Their numbers varied markedly from season to season, but in all soils these bacteria appeared most plentiful during July. Regular cropping of the land led to larger numbers than cropping interspersed with periods of rest. So far four species have been isolated which, under laboratory conditions, are capable of fixing atmospheric nitrogen. Further work will involve the study of these organisms under a range of crops and methods of cultivation, to determine the conditions most favourable to their activity.

This work on nitrogen-fixing organisms is in its infancy, but much progress can be confidently expected from a combined biological and chemical approach. Chemical investigation can reveal the scale and direction of changes in the total nitrogen-content of the soil. Unfortunately the amounts of nitrogen present in Gezira soil, although small as compared with those of most temperate soils, are yet very large when judged against

those added by nitrogen-fixing organisms; so the latter's contribution tends to be obscured by the inherent variation in total nitrogen from one part of a field to another. The activity of nitrogen-fixing organisms cannot be measured merely by the increases in those forms of nitrogen readily available to crops, i.e. nitrate and ammonia, for these are also produced from the breaking-down of crop residues and other complex forms of nitrogen already present in the soil.

From the chemical aspect B. W. Whitfeild and A. J. Henry in 1933–4 studied the activity of those organisms concerned in the formation of nitrate, by measuring the rate of nitrification of ammonium sulphate in soil. With rise in temperature there was an increase in the rate of production of nitrates, but also a yet more rapid increase in the rate of its conversion into complex forms of nitrogen. Whereas at 25° C. the amount of nitrate thus converted was comparatively small, at 40° C. it was considerable, the nitrate disappearing almost as rapidly as it was formed. They also noted that nitrification occurred just as readily in complete darkness as in diffuse daylight, but that it was almost completely inhibited when the soil was waterlogged. In the Gezira, T. N. Jewitt found, as was to be expected, that the rate of nitrification of ammonium sulphate was rapid, and that of organic fertilizers, such as cotton-seed cake, considerably slower. He found that the first micro-organisms to attack organic manures were not bacteria but fungi, the bacteria only later becoming active. The fungi appeared capable of locking up considerable amounts of nitrogen in a form unavailable, at least temporarily, for nitrifying bacteria. Since these fungi appeared most active in semi-dry soil, they may play an important part in the field by locking up nitrogen which would otherwise be available to crops, their activity being stimulated by the frequent drying of the surface layers.

Summarizing the work of past years on Gezira soils in relation to the yield of cotton, Greene concludes that cotton yields depend on (*a*) some fairly permanent chemical and physical properties of the soil, the better soils possessing relatively low salt-content and alkalinity, relatively large amounts of organic matter and nitrogen, and relatively high permeability; and (*b*) some properties which are subject to considerable modification by soil management, in respect of choice of rotation, use of fertilizers, irrigation practices, &c. These are conclusions of practical importance, since it is possible when developing new land to select (*a*) only the better soils and (*b*) methods of soil management which will make the best use of the areas selected.

II. HUSBANDRY

The inadequate rainfall of that part of the Sudan to the north of Khartoum has meant that cropping there has been limited to such areas as can be irrigated from the rivers. Experimental work, following the course of the country's historical development from the north southwards, centred first round irrigated crops at Shambat, later extended to the Gezira, and only recently has embraced the rain-crops of the more southerly areas, where, even up to the present, the work has been only of a preliminary nature.

IRRIGATED CROPS

Systematic experimental work on irrigated crops began with the inauguration of the Central Research Farm at Shambat, under E. R. Sawer, in 1912. Simple experiments indicated that at Shambat cotton should be sown about 10 July, spaced at 45 cm. between holes along ridges 100 cm. apart, and lightly watered at 10-day intervals. The experiments showed no responses to phosphate and potash, but large responses to nitrogen, added either as farm-yard manure or as nitrate of soda, all of which supported W. Beam's conclusions based on the chemical analyses of soil samples, described in the foregoing section. 'Lubia' (*Dolichos lablab* Linn.) was found to be the best green manure. How well many of these results of 30 years ago apply to-day, not only at Shambat but to large tracts of irrigated land, will be evident in the following pages.

With the opening of the Gezira Research Farm in 1918 the main field experiments shifted to the Gezira, and the experiments made there have constituted a large part of the annual research programme ever since. From 1926 they have increased in number and also, in accordance with R. A. Fisher's statistical methods, in complexity, until there has accumulated a mass of experimental data on the management of crops under artificial irrigation which has value, not only locally in the Gezira, but as a contribution to the annals of agricultural science. In the following account the most informative experiments have been selected as most suitable for description here, but this must not obscure the importance of the early work which made possible the later experiments. No reference is made here to varieties of crops, since they have a section to themselves. Throughout the present section yields of cotton, expressed as kantars per feddan, refer to seed-cotton (lint plus seed).

Rotation of Crops

The Gezira Scheme was devised primarily for the cultivation of cotton. Since dura was already grown on rain in the area before it was canalized, there seemed no reason to expend irrigation water upon it. Thus, although in the earliest years of the Taiyiba pump-scheme, 1911 and onwards, dura was tried as well as wheat and legumes, at the Barakat pump-scheme, started in 1914, no crops were grown other than cotton, the land resting between whiles. Later, because of the value of the irrigated dura to the Sudan in years of drought, and of the eagerness of the Sudanese cultivator to grow his own food crop, dura was sown increasingly, until, when the area was greatly extended by the opening of the Sennar Dam in 1925, dura was included with 'lubia' and cotton in a three-year rotation. To fit dura into the rotation was not easy, for cotton yields suffered and the dura itself did not yield well; and little experimental information was available on three-year rotations. But even now, with the accumulated knowledge gained from 17 years of experiments, within the limits of cropping once every three years with cotton and including dura, no major improvements on the early rotation can be suggested.

The principal rotation experiments are the Three-Course Rotations experiment (v. plan of the Gezira Research Farm on p. 422) and the Combined Rotations experiment. The former was designed by E. M.

Crowther in 1925 and the latter by M. A. Bailey and E. M. Crowther in 1931. They have been supervised by successive Inspectors of Agriculture, mainly V. P. Walley, E. Mackinnon, E. R. John, and W. A. Porter. All crops are sown during the rains, July and August, irrigations being continued until October, January, and March for dura, 'lubia', and cotton respectively; hence only a single crop is grown each year. In earlier literature of the Gezira Scheme the interval during which the agricultural land remained uncropped has been loosely termed 'fallow'; but, since 'fallow' in temperate countries generally denotes land which is repeatedly cultivated to eliminate weeds, the word does not strictly apply to uncropped land in the Gezira rotation. This is more correctly styled 'resting land' or, in Arabic, 'būr'.[1]

The annual yields of cotton in these experiments are shown graphically in Figs. 184 and 185.

Three-Year Rotations. The yields of the Three-Course Rotations experiment,[2] averaged over 17 years, are as follows:

Rotation			*Yields of seed-cotton*	
1st year	*2nd year*	*3rd year*	*Kantars per feddan*	*Percentage of rotation 'a'*
a. 'Lubia'	Resting	Cotton	4·50	100
b. Resting	Resting	Cotton	4·21	94
c. Dura	'Lubia'	Cotton	4·06	90
d. Dura	Resting	Cotton	4·01	89
e. Dura	Dura	Cotton	3·02	67

Cotton yields were highest where dura was omitted from the rotation, and 'lubia' followed by resting was superior to two years' resting. From a statistical examination of the yields of this series of experiments, recently completed by F. Crowther and W. G. Cochran, there were indications that the superiority of 'lubia'–resting–cotton over resting–resting–cotton was becoming progressively more marked as the experiments continued. Neither of these rotations can be adopted permanently in the Gezira Scheme so long as dura also is needed and has to rotate with the cotton.

The dura crop did least harm to cotton yields when grown in the year following cotton, as is shown in this comparison from the Combined Rotations experiment:

Rotation	*Yields of seed-cotton* — *Kantars per feddan*	*Percentage of rotation 'a'*
a. Resting–resting–cotton .	3·94	100
b. Dura–resting–cotton . .	3·49	89
c. Resting–dura–cotton . .	2·60	66

It must be explained of these tables of the Combined Rotations experiment, which are based on the data used for the statistical examination, that such a table as the above, involving cotton and dura only, represents

[1] See also p. 6.

[2] Here and in the Combined Rotations experiment the dura straw and 'lubia' hay, after weighing, have been consumed on the plots, usually by cattle. From 1945 the dura straw is to be removed.

one phase of what is in reality a 6-course rotation, 'lubia' replacing dura in the other phase. Similarly the so-called 4-course rotation, also consisting of the two phases, is in reality an 8-course. It is possible that the results in the dura phase are slightly biased by residual effects from the 'lubia' phase, but any such effects are believed to be so small as not to modify the conclusions.

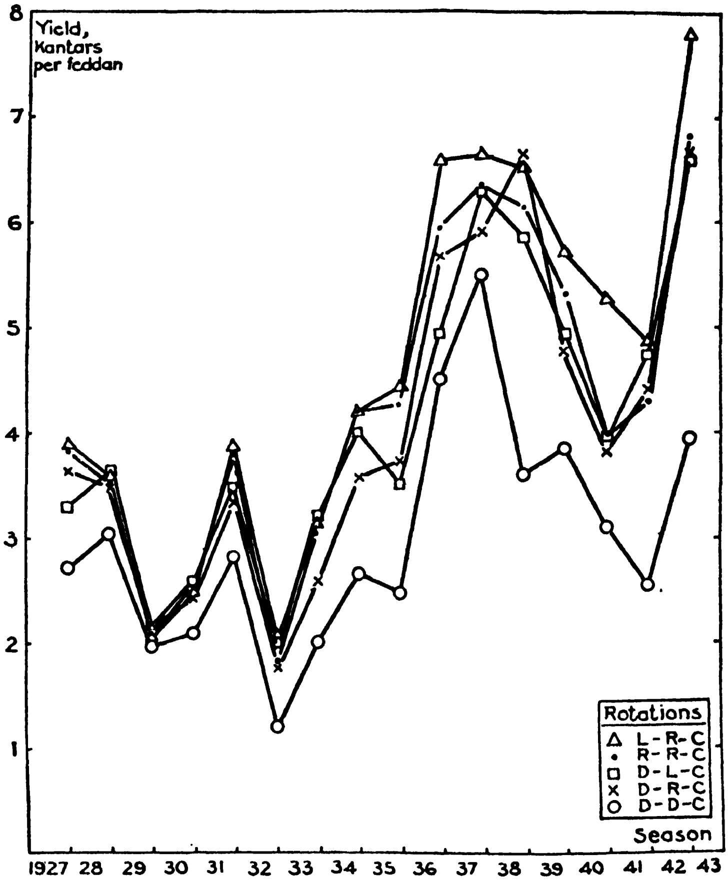


FIG. 184. Cotton yields of five 3-year rotations (Plots 10–15) at the Gezira Research Farm (C = cotton; D = dura; L = 'lubia'; R = resting land) (F. Crowther and W. G. Cochran, *J. Agr. Sci.*).

When dura was sown the year after cotton (DRC) the yield of the next cotton crop was 89 per cent. of that after two-years' rest (RRC); and where dura immediately preceded cotton (RDC) the yield was only 66 per cent. of that following a double resting period. Thus, unless there was a full year's rest after the dura crop, the yield of the cotton fell sharply.

If dura must be grown with cotton in a three-year rotation the only place for 'lubia' is instead of the rest,[1] and there the benefit from the 'lubia' is

[1] At the Gezira Research Farm, where there are special facilities for water-supply, many of the plots are on a rotation where 'lubia' is sown in winter immediately after the removal of the dura crop and on the same land. This rotation

almost negligible, as can be seen from the yields of rotations *c* and *d* in the Three-Course Rotations experiment. To give maximum benefit 'lubia' should follow the year after cotton, as is shown in the following yields of the 'lubia' phase of the Combined Rotations experiment.

Rotation	*Yield of seed-cotton*	
	Kantars per feddan	*Percentage of rotation 'd'*
d. Resting–resting–cotton	3·94	100
e. 'Lubia'–resting–cotton	4·21	107
f. Resting–'lubia'–cotton	3·60	91

Although 'lubia' improves the cotton yield when sown the year *after* cotton (LRC) it lowers the cotton yield when sown the year *before* cotton (RLC).

The conclusion from these results is that, for high cotton yields, the best three-year rotation is 'lubia'–resting–cotton, but where dura has to be included, the rest after it should be as long as possible. The actual rotation adopted over the Gezira Scheme from the opening of the Sennar Dam was, as shown in the diagram at p. 777 in Chapter XXVII, a combination of these two, for on 10 feddans the cotton was followed by 5 feddans of 'lubia' and 5 feddans of dura, these latter crops changing places every 3 years; and the third year was entirely resting.

The experimental results confirm Beam's forecast of 1911 on the need for a legume to improve the nitrogen status of the soil, but residual benefit to cotton from a crop of 'lubia' does not follow invariably. Experience suggests that on the commercial crop of the Gezira Scheme the superiority of 'lubia' over resting, in rotation with cotton, is even less marked than in these experiments. Moreover 'lubia' is disliked because after it the land tends to be weedy, perennial weeds especially proving troublesome.[1]

Need for a Four-Year Rotation. So far attention has been directed only to the yield of cotton, but the production of dura and 'lubia' must also be considered. Dura grain is the staple diet of the people, and both dura straw and 'lubia' hay are required for milk production. Unfortunately in the Gezira the yield of dura when sown in a three-year rotation after cotton is relatively low. This is illustrated from the Combined Rotations experiment in the following yields of heads and straw:

	Weight (rotls per feddan, air-dry)	
	Heads	*Straw*
a. Dura after cotton	816	2,717
b. ,, ,, 1 year's rest	1,231	3,964
c. ,, ,, 2 years' rest	1,378	4,510

cannot be used on a large scale in the Gezira Scheme because of the limited water-supply from January onwards.

[1] From the point of view, however, of the social emergence of the Gezira farmers 'lubia' is a very important crop.—*Editor.*

Dura after one year's rest yielded 51 per cent., and after two years' rest, 69 per cent. more heads by weight than after cotton. Thus at least a full year's rest should be allowed before dura is sown if greatly reduced yields are to be avoided. To achieve this, and at the same time maintain the yields of cotton, necessitates a four-year rotation, and when the present Gezira rotation was designed in 1933 the need for this resting year before dura was taken into account.

In a comparison of rotations of different lengths where the only crop grown is cotton, the value of three successive years resting, over both two years and one year, is illustrated in Fig. 185 *a*. When dura and 'lubia' are

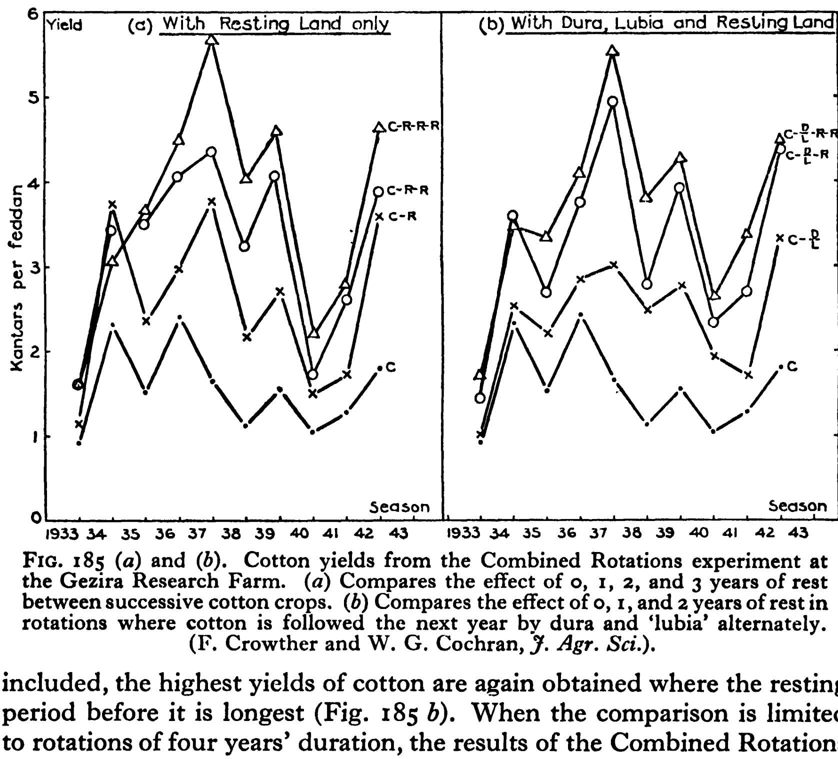


FIG. 185 (*a*) and (*b*). Cotton yields from the Combined Rotations experiment at the Gezira Research Farm. (*a*) Compares the effect of 0, 1, 2, and 3 years of rest between successive cotton crops. (*b*) Compares the effect of 0, 1, and 2 years of rest in rotations where cotton is followed the next year by dura and 'lubia' alternately. (F. Crowther and W. G. Cochran, *J. Agr. Sci.*).

included, the highest yields of cotton are again obtained where the resting period before it is longest (Fig. 185 *b*). When the comparison is limited to rotations of four years' duration, the results of the Combined Rotations experiment, for the effect on the yields of cotton of replacing a year's rest by (A) dura and (B) 'lubia', are as follows:

	Yields of seed-cotton			*Yields of seed-cotton*	
A. Rotations with dura	*Kantars per feddan*	*Percentage of 'a'*	*B. Rotations with 'lubia'*	*Kantars per feddan*	*Percentage of 'e'*
a. RRRC .	4·70	100	*e.* RRRC	4·70	100
b. DRRC .	4·20	89	*f.* LRRC	4·65	99
c. RDRC .	3·56	76	*g.* RLRC	4·44	94
d. RRDC .	2·66	57	*h.* RRLC	3·83	81

Dura lowers the yield of the cotton whatever its place in the rotation, and 'lubia' also is harmful to the cotton unless the land is allowed to rest

for at least a year after it. As with the three-course rotations, both dura and 'lubia' should be sown so as to allow as long an interval as possible between them and the following cotton crop.

To summarize: a resting year is necessary before dura and as long a rest as possible before cotton, commensurate with the cost of land, canalization, &c. 'Lubia' has some advantage over resting in the year following cotton in a three-year rotation, but should not be sown in the year immediately preceding cotton, since in that year the land must be allowed to rest.

The results are in harmony with the existing Gezira rotation (v. diagram at p. 777 in Chapter XXVII for details). This provides (*a*) either 2 resting years or 'lubia'–resting before cotton, and (*b*) one resting year before dura. Inevitably, since crops are sown in July–October, this means an average of only one cotton crop in four years, but it provides the same proportion of dura and 'lubia' to cotton as in the original three-year rotation.

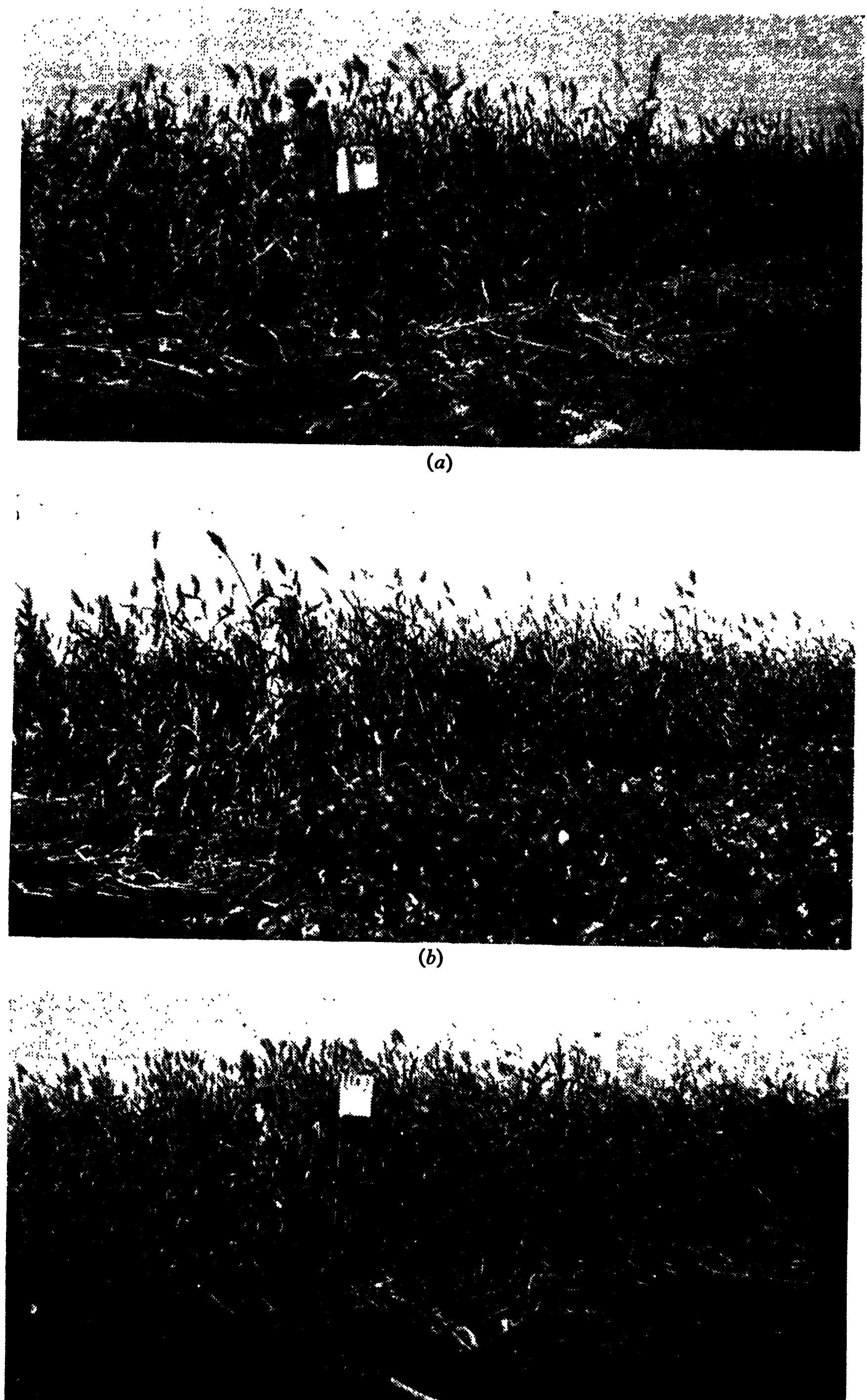
This eight-year rotation need not be considered the final one, for increased population in future years may not allow that only half the land should be cropped in any one year. Information is required, and experiments are in progress at the Gezira Research Farm, upon possible means of improving the three-course rotation, with special reference to improved yields of dura and increased residual benefit from 'lubia'. Future work must also include a study of possible modifications in the rotation to suit individual parts of the Gezira Scheme and the pump-schemes. All have their local problems and different amounts of rainfall, and these, together with differences in the soils, may necessitate a modification of the rotation found most suitable for conditions as existing at the Gezira Research Farm.

Cotton Culture

During the period 1920 to 1932 numerous experiments were made at the Gezira Research Farm, mostly by Walley, to determine the optimum date of sowing, optimum spacing, and the response to manuring. The results, the average of all available data, are summarized on p. 468 in kantars per feddan.

In these experiments all treatments were not represented every year, and for this table adjustments have been made by interpolation to obtain valid comparisons. Although the results were variable and the differences mostly small, it was apparent that, for conditions existing then, the largest yield resulted when cotton was sown in mid-August, at a spacing of 40 to 50 cm. between holes, and thinned to three plants per hole. Originally on the commercial area, the crop was sown earlier than mid-August at a wider spacing, and was thinned more drastically, usually to two plants, but gradually general practice has been brought into line with these experimental results. Large increases in yield were obtained in the experiments with ammonium sulphate, especially when it was buried at the time of application, the optimum date being at least 2 to 4 weeks before sowing.

All these results were obtained from simple single-factor experiments (mostly Latin squares); for example, different spacings were compared while all other conditions remained as uniform as possible. In 1928



(*a*)

(*b*)

(*c*)

FIG. 186. Dura in the Combined Rotations experiment: (*a*) Plot 106, dura after cotton; (*b*) Plot 148, dura after land had rested for 1 year; and (*c*) Plot 143, dura after land had rested for 2 years (*photo H. Greene*).

F. G. Gregory and F. Crowther started experiments to compare factors in combination to study how the response to one factor depended upon

Date of sowing		*Spacing*		*Number of plants per hole*	
Period	*Yield (av. of 12 years)*	*Distances between holes*	*Yield (av. of 6 years)*	*Number*	*Yield (av. of 3 years)*
15–29 July . .	2·40	20–30 cm.	2·86	1	3·24
30 July–12 Aug. .	2·51	40–50 cm.	2·94	2	3·31
13 Aug.–26 Aug. .	2·64	60–70 cm.	2·80	3	3·59
27 Aug.–9 Sept. .	2·50	90–110 cm.	2·66	4 or 5	3·49
10–23 Sept. . .	1·84	(Distance between ridges 80 cm.)			

another. For example, under commercial conditions it was never possible to sow the entire area within a few days, for sowing-date had to depend upon the date of arrival of irrigation water or on the distribution of the rainfall, and it was possible that the best spacing might vary with date of sowing.

Manuring with Ammonium Sulphate

Amount of nitrogen		*Date of application**		*Manner of application**	
Rate	*Yield (av. of 12 years)*	*Date*	*Yield (av. of 12 years)*	*Method*	*Yield (av. of 3 years)*
Unmanured	3·32	2 to 4 weeks before sowing	4·36	Broadcast	4·10
200 rotls per feddan	3·99	From sowing to 2 weeks after sowing	4·08	Buried between ridges	4·54
400 rotls per feddan	4·43				
600 rotls per feddan	4·74	4 to 6 weeks after sowing	3·97		

* The amount of nitrogen applied in these experiments was usually 200 rotls per feddan.

The first experiment on factors studied in combination compared three rates of manuring at each of three levels of watering. The yields were:

Amount of water	*Amount of nitrogen*		
	Nil	*1½ N*	*3 N*
Light . . .	1·38	1·98	2·28
Medium . .	1·54	2·45	3·04
Heavy . . .	1·58	2·80	3·79

The nitrogen was applied as ammonium sulphate, 6 weeks after sowing, at rates of 300 rotls (1½ N) and 600 rotls (3 N) per feddan. The irrigation was

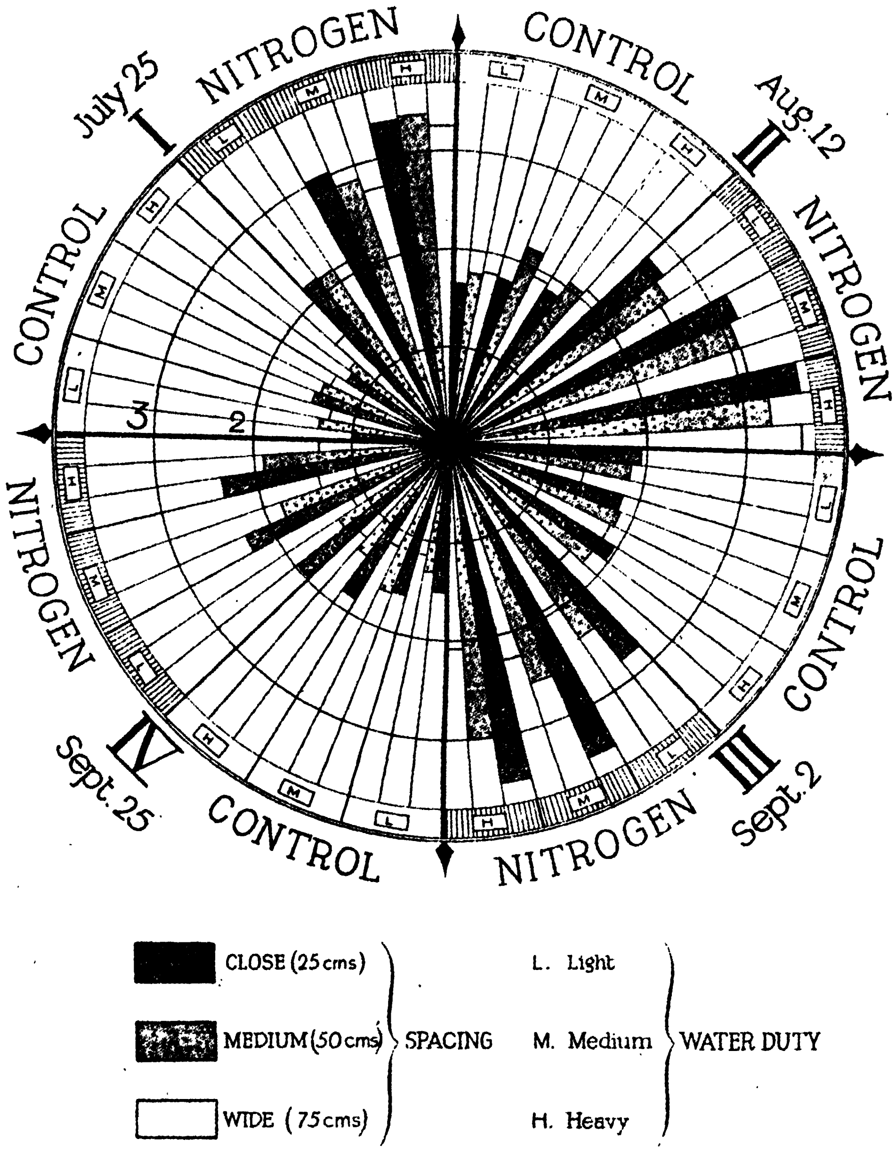


FIG. 187. Cotton yields from the Four-factor Experiment made at the Gezira Research Farm in 1929–30. The diagram shows the yields along the radius. The 72 treatments of the experiment are divided first into the four quadrants according to sowing-date, each quadrant being sub-divided according to manuring, each manurial treatment according to irrigation, and finally each irrigation treatment according to spacing. (*Gregory, Crowther, Lambert, J. Agr. Sci.*).

FIG. 188. Application of ammonium sulphate in fertilizer experiments at the Gezira Research Farm. The fertilizer is divided into the correct amount per furrow. Here the fertilizer is being applied when the cotton has just appeared above the ground. The ridges, originally comparable with those shown in Figs. 164 and 168, have been almost flattened by rain (*photo F. Crowther*).

the same for all plots until the manure was applied, but afterwards, though all plots were irrigated at the same times, the amounts of water differed.

Yields were lowest where unmanured land was lightly watered and highest where heavily manured land was heavily watered. The maximum increases from manuring were, with light watering 0·90 kantars per feddan, and with heavy watering 2·21 kantars per feddan. Similarly, in the absence of manure heavy watering increased yield by only 0·20 kantars per feddan, whereas with the heavy application of manure the increase from heavy watering was more than seven times as great. Thus it appeared that some of the benefit from manuring might be lost if the water were not suitable in amount, and that the limited water of an irrigation scheme could be utilized to better effect by adjustment of the amount of water to the nitrogen-status of the soil.

From these results it was evident that a survey of the principal factors involved in the management of the cotton crop, if these factors were studied in combination, would educe much new information. Accordingly Gregory, Crowther, and A. R. Lambert in 1929–30 carried out a very large four-factor experiment, comparing (*a*) sowing-date, (*b*) amount of water, (*c*) crop-spacing, and (*d*) manuring, in all combinations. The yields of the experiment, which involved the comparison of 72 treatments and of 288 sub-plots, are reproduced in Fig. 187, and similar results were obtained when the experiment was repeated the following season. The diagram shows the yield of each treatment along the radius, concentric circles marking yields of 1, 2, and 3 kantars per feddan. The treatments are grouped first according to sowing-date, one to each of the four quadrants. Each quadrant is subdivided, half for manured treatments and half for unmanured. In turn, these half-quadrants are subdivided into the 3 amounts of water, and finally each unit of water, into the 3 spacing treatments.

The main results may be summarized as follows:

1. Yields were highest with the August sowings, whether manured or not.
2. Response to manuring was greatest with the earliest sown cotton and fell progressively with delay in sowing-date, late-September sowings giving but little response.
3. Spacing had little effect with early sowings but a large effect with late sowings.
4. The effects of water-supply were considerable where early sowings received manure; otherwise they were small, and in all cases tended to disappear with advancing sowing-date, irrespective of manuring.

It is evident from Fig. 187 that similar high yields can be obtained over a wide range of sowing-dates, although the conditions required to produce these yields are different. To obtain them with sowings made in late July manuring is essential, combined with heavy irrigations, but spacing is incidental. With sowings made in mid-August manuring again gives large increases, but high yields are obtained over widely varying rates of irrigation; and again spacing is unimportant. With sowings throughout September spacing is all-important, high yields being obtained only with the closest spacing; but changes in rates of irrigation have only a minor effect.

So copious was the information extracted for guiding commercial practice that further experiments as elaborate as this have not been necessary for cotton. Close spacing of late sowings is now a recognized practice. Up to the outbreak of war ammonium sulphate was being used on an increasing scale, and in 1938–9 was applied to 20,000 feddans, directions as to its use being based on the findings of these and other experiments made at the Gezira Research Farm.

Subsequent experiments have confirmed the validity of the major conclusions for most parts of the Gezira Scheme, and those made since 1930–1 have been concerned with the different facets of specific problems, of which examples are described below.

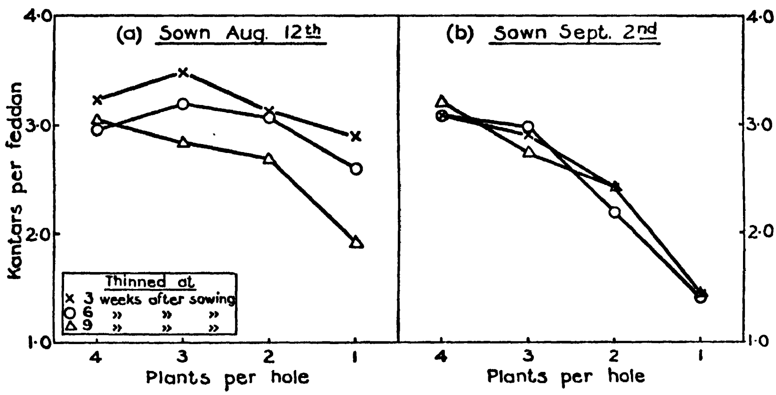


FIG. 189. Cotton yields from an experiment made at the Gezira Research Farm comparing the date and degree of thinning for sowings made in (*a*) mid-August, and (*b*) early September (A. R. Lambert and F. Crowther, *Emp. J. Exp. Agr.*).

Date and Degree of Thinning. Walley had shown that thinning to three plants per hole gave the highest yield, and in 1932–3 Lambert and Crowther investigated whether this conclusion was valid for cotton sown and thinned at different dates. The factors were studied in combination and details of the treatments and the yields are shown in Fig. 189. When cotton was sown at the normal date, mid-August, early thinning was essential for high yields, especially if the thinning were drastic, to one or two plants per hole. When sowing was delayed until early September the requirements were quite different; date of thinning was unimportant, the yield being controlled by the number of plants left in the holes after thinning; drastic thinning greatly reduced yield and four plants left per hole were superior to three plants. The prime importance, for late sowings, of the number of plants left per feddan was demonstrated also in the four-factor experiment described above, which showed the importance of close spacing for late sowings (v. Fig. 187).

Irrigation Experiments. These have been in progress since 1918, but the difficulty of conveniently measuring water for small plots, and of replicating the treatments when large plots are used, has hampered the work on the irrigation requirements of Gezira crops. The original experiment started in 1918 continued for 13 years, but in it the treatments were not replicated. The only difference demonstrated was that the lightest

irrigations, of 300 to 350 m³. per feddan, gave lower yields than the rest. The importance of heavy waterings with early-sown crops and with those manured was exemplified in the combined-factor experiments already described (v. Fig. 187).

On the subject of waterlogging, Crowther has shown that water standing on the land *before* sowing, though it may persist for one or two weeks at a time, has little or no harmful effect on the growth of the following cotton crop. If water stands on the land *after* sowing, a common occurrence in the Gezira during late August and September when rain falls on newly irrigated land, then the crops, dura and 'lubia' as well as cotton, may suffer acute leaf-yellowing and stunting from waterlogging, the check to growth of cotton often being followed by loss of crop. After the rains have ceased, in mid-October, the crop benefits by heavy watering whether supplied in single applications or by closer intervals, but the differences in yield from a wide range of treatments are usually small. This is shown in the following average yields, of two years' well-replicated experiments made by the Sudan Plantations Syndicate Ltd., in conjunction with the Irrigation Department and the Agricultural Research Staff. Three watering intervals were compared, and more than 4,000 feddans of land, widely distributed through the Gezira, were employed.

Interval	*Yield*	
	Kantars per feddan	*Percentage*
8-day	4·77	95
11-day	5·17	103
14-day	5·03	100

The comparison of intervals covered the period of hottest weather and of most active vegetative growth, October and November, all areas reverting to the standard interval of 14 to 16 days from December onwards. The customary interval in commercial use during October and November is now 12 days, and this is fully supported by this experiment, the indication being that a day's variation either way is unimportant.

In the Gezira Scheme the question of watering during the picking season is of especial concern since at this time only stored, and therefore limited, water is available, and experimental results have shown that considerable economy in water would be possible with but little detriment to the crop. The normal practice is to water regularly until the end of March, the supply ceasing abruptly in early April. The following are yields, averaged from two years' experiments conducted by E. R. John, for various dates of cessation of irrigation:

Final irrigation	*Yield Kantars per feddan*	*Loss compared with normal*
8 Jan.	4·89	0·37
6 Feb.	4·90	0·36
18 Feb.	5·26	0
26 Mar. (normal). .	5·26	..

The data show no loss of crop when waterings ceased 6 weeks earlier than usual, and cessation even 2½ months earlier than usual reduced yield by only 7 per cent., this loss being in the latest, and therefore lowest-grade, cotton. Since from 1 January the Gezira Scheme utilizes entirely stored water, the results indicate that, with only slight reduction in cotton yield, a large reduction can be made in the amount of stored water applied per feddan, the economy rendering water available for cropping a larger area.

Manuring Experiments. These have covered a wide range of investigations. Ammonium sulphate was the only fertilizer extensively used up to 1939 when the war stopped supplies, but experiments have shown that nitrate of lime gives consistently larger increases in yield than ammonium sulphate, per unit of nitrogen, the averaged yields of five years' experiments being as follows:

	Yield	
	Kantars per feddan	*Percentage*
No nitrogen	5·89	100
Nitrate of lime	7·75	132
Ammonium sulphate	7·34	125
Additional increase with nitrate of lime	+0·41	..

The increase in yield per unit of nitrogen with nitrate of lime was 28 per cent. greater than with ammonium sulphate. Other factors, however, must be considered in deciding which is preferable for use commercially. Ammonium sulphate may leave the greater residual benefit in the soil, and H. Greene has shown that its continued use lowers appreciably the alkalinity of the soil; also it is more easily handled and costs less per unit of nitrogen. It is doubtful, therefore, whether on balance, nitrate of lime would have an advantage over ammonium sulphate in commercial use.

These field results led T. N. Jewitt to investigate the differences in the two fertilizers from the chemical standpoint, and he found that when ammonium sulphate was in contact with moist Gezira soil, nitrogen was lost in the form of ammonia through reaction with the soil alkalis, a result which may well explain the inferiority of fertilizers containing ammonium salts under Gezira conditions. Jewitt also found that this loss of ammonia was greatly reduced when the fertilizer was covered with soil, and this conforms with the early results of Walley, already given, which showed the superiority of buried over broadcast, and therefore exposed, applications of ammonium sulphate.

The use of dung has been examined principally from the standpoint of restoring to the soil some of the nitrogen removed by the crops. As the animals are not enclosed in buildings and yards but remain in the open in or near the fields, most experiments have compared the effect on cotton yield of feeding measured quantities of dura straw and 'lubia' to animals on the resting land within two years before cotton-sowing. Usually sheep have been preferred to cattle because they are the more easily folded on small sub-plots. The following are the cotton yields averaged from

seven years' results of an experiment designed by M. A. Bailey and H. Greene to compare the manurial value of various feeding rations:

	Yield	
	Kantars per feddan	*Percentage*
1. Control; no manure	4·38	100
2. Fixed ration per feddan fed 18 months before cotton-sowing	4·99	114
3. Fixed ration per feddan fed 6 months before cotton-sowing	5·21	119
4. As '3', but cotton-cake added to ration . .	5·79	132
5. The manure, produced after feeding the ration in '3' to stock penned in farm-yard, added 3 months before cotton-sowing	5·23	119

The fixed ration comprised the average produce (excluding dura-heads) from 2 feddans of dura and 1 feddan of 'lubia'; the amount of cotton-seed cake was equivalent to 60 rotls nitrogen per feddan, the produce of seed from 3 feddans of cotton. Thus the total ration per feddan in the maximum treatment represented the product of 6 feddans of cropped land. The pen-manure in treatment 5 was the result of feeding the same fixed ration as in treatments 2 and 3, the impregnated soil being carted out to the plots.

All treatments increased yield, but the largest increase was where cotton-cake was included in the ration. In that case the increase over the unmanured plots was 1·41 kantars per feddan or 32 per cent. But to obtain such an increase from a single feddan the surplus produce of 6 feddans of cropped land was necessary. Obviously a cultivator, such as a Gezira tenant, with 10 feddans of cotton and 5 feddans each of dura and 'lubia', can manure only a small proportion of his cotton at this rate, since it would need the produce of 60 feddans of cropped land to manure his 10 feddans of cotton. Any manure used on the rest of his cotton must be purchased, either as cotton-cake or sesame-cake for direct application to the land or as imported fertilizers. Cotton-cake applied directly to the land increases yield commensurately with ammonium sulphate, as is shown by the results of a second experiment designed by Bailey, the yields averaged over four years being:

	Yields of cotton	
	Kantars per feddan	*Percentage*
Control; no manure	5·25	100
Cotton-seed cake (equivalent to 40 rotls nitrogen per feddan)	6·14	117
Ammonium sulphate (equivalent to 40 rotls nitrogen per feddan)	6·09	116

In their immediate benefit to the following cotton, evidently oilcakes as a source of nitrogen are as effective as inorganic fertilizers. It follows also

that the value of these organic manures lies in the nitrogen they supply, the additional organic matter having no observable effect on cotton yields. Although, strictly, the two experiments are not comparable, it seems clear that the manurial residue of cake when fed to sheep is little more than half that of the cake applied directly; for the equivalent of 60 rotls nitrogen, when fed to sheep, produced an additional yield increase, over that of the basic ration, of only 0·58 kantars per feddan, or 13 per cent., whereas the equivalent of 40 rotls, i.e. two-thirds the amount of nitrogen, applied directly to the soil, caused a yield increase of 17 per cent. Against this result, of course, must be set any gain in weight of the sheep.

Dura Culture

The improved cotton yields since 1934–5 have permitted more attention to be given to the dura crop, and the urgency of the war-time need for food crops has since 1939 further stimulated interest in it. Even so, information is still scanty and much work remains for the future.

The place of dura in the rotation has already been described, and, where the land first rests for a year, yields are usually high. A complete year's rest, however, can be obtained only by the introduction of a four-year rotation, as in the Gezira Scheme. Since elsewhere, for example Abd el Māgid and the White Nile pump-schemes, the three-year rotation persists, research is still needed on measures for improving yields when dura is sown immediately after cotton.

The most numerous experiments so far made at the Gezira Research Farm, excluding variety trials, have been concerned with the extent of the residual effect of the manure, chiefly ammonium sulphate, applied to the preceding cotton. The residual effects averaged from 25 experiments between 1927–8 and 1942–3, after adjusting the yields by interpolation to allow a valid comparison, were as follows:

	Yields of dura			
	Heads		*Straw*	
Applied to cotton	*Rotls per feddan*	*Percentage*	*Rotls per feddan*	*Percentage*
0 N Nil . . .	1,030	100	2,765	100
1 N 40 rotls nitrogen per feddan	1,115	108	3,030	110
2 N 80 rotls nitrogen per feddan	1,251	121	3,293	119
3 N 120 rotls nitrogen per feddan	1,423	138	3,384	122

The benefit derived by the dura crop from the lower rates is small, but the differences are sufficiently regular for it to be assumed that dura yields will be from 5 to 10 per cent. higher when the preceding cotton has been manured at the standard rate (1 N).

The first multiple-factor experiment with dura was made as recently as 1941–2 when Crowther, in a four-factor experiment similar to that described for cotton, compared various combinations of variety, spacing, manuring, and degree of thinning (v. Figs. 190 and 192). Sowing-date

varies but little for dura, since the crop is always sown as early as rainfall becomes adequate or irrigation-water available, and so variety replaced sowing-date in the dura experiment. The averaged results of two years' experiments are shown in Fig. 191, which gives details of the treatments. Two varieties, one tall (Feterita, Fig. 194) and one short (Dwarf Hegari, Fig. 193), were compared at different levels of the other treatments.

Comparison of the graphs stresses the outstanding importance of nitrogen in controlling the yield of grain per feddan. Spacing and thinning had only

FIG. 190. Four-factor experiment on dura at harvest-time, showing the size and arrangement of sub-plots and the differences between them in amount of crop. The soil in the central sub-plot is more clearly seen than in others because of the great reduction in amount of the root-parasite *Striga hermonthica* following the application there of nitrogenous manure (*photo by F. Crowther*).

minor effects, whereas manuring trebled the yields of both varieties. It is largely this dependence of dura upon supplies of available nitrogen which explains both the loss in yield when it follows cotton and the benefit of a prolonged rest.

Large differences in spacing had but little effect on grain yield. When the number of plants per feddan was doubled the yield per plant was halved; and when the number of plants was halved the yield per plant was doubled, yield per feddan remaining approximately constant and controlled almost entirely by the supply of nitrogen to the roots, irrespective of the number of plants involved. Closer spacing produced more straw per feddan, but the increase within the range examined was only 34 per cent. as compared with 85 per cent. from manuring.

Drastic thinning to two or four plants per hole, although giving a slight but not significant increase in grain yield, lowered the yield of straw; thus thinning of irrigated dura sown in the normal manner appears unnecessary.

Since both tall and dwarf varieties depend for improvement in yield upon increase in the supplies of available nitrogen, the lack of rest before dura in the three-course rotation can be offset by manuring; but despite the great increases in yield effected, the market value of the crop does not normally justify expenditure on manures.

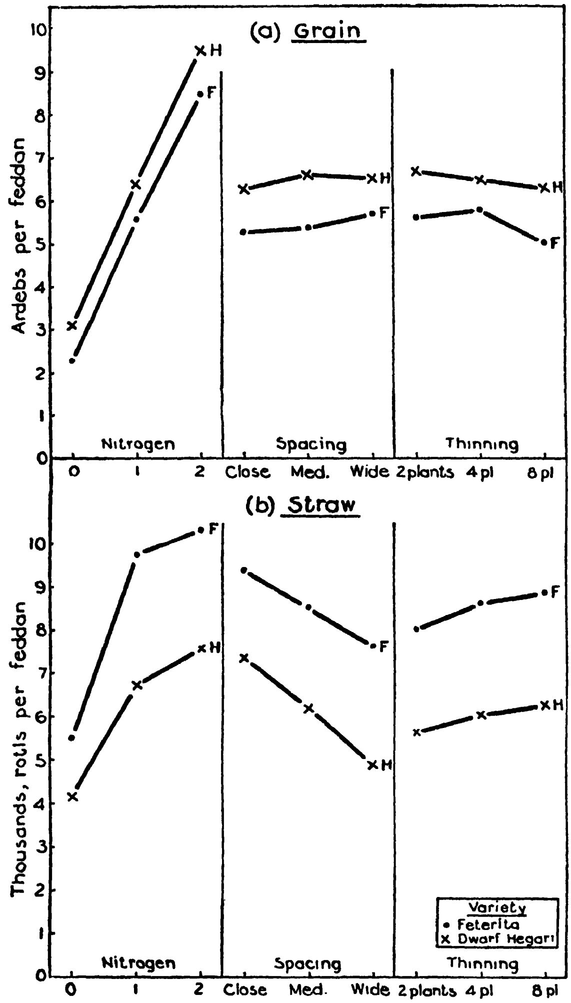


FIG. 191. Yields of (*a*) grain, and (*b*) straw from the dura four-factor experiment at the Gezira Research Farm, the averaged results of 1941–2 and 1942–3 (1 ardeb of dura weighs 336 rotls) (F. Crowther (original)).

Recent experiments by Crowther suggest that one means of improving dura yields on the three-course rotation is by a slight change in the management of the cotton crop at the end of its growth, three or four months before the dura is sown. Normally irrigations cease at the end of March and the cotton plants are removed by root-pullers in April or May. In experiments where cotton was pulled earlier than usual and irrigations

were continued till the usual date of cessation, yields of the following dura were considerably improved. The yields averaged from two years' experiments were:

	Treatment of cotton		*Yield of dura in rotls per feddan*	
	Pulling	*Final irrigation*	*Heads*	*Straw*
Normal	3 May	3 Apr.	550	2,803
Early pulling	6 Mar.	3 Apr.	976	4,577
Increase	..	..	78 per cent.	63 per cent.

The dura was sown on 20 July and irrigated. Early pulling of the cotton combined with irrigating the land after pulling increased the yield of heads by 78 per cent. and of straw by 63 per cent. The effect cannot as yet be fully explained, but the results are of twofold interest in that they demonstrate an improvement in the productivity of the three-course rotation and also imply that a relatively moist soil may be preferable to dry soil during the resting period between crops. Further investigations are required to reconcile this with the need for a thorough drying-out of the heavy Gezira soil by uncultivated intervals, which has hitherto been deemed an essential of sound agricultural practice, to improve tilth, and, through extensive and deep cracking, to aerate the subsoil. One obvious drawback of relatively moist resting land is that it encourages the survival of perennial weeds, which normally suffer a check when the soil is left dry and deeply cracked.

Control of Weeds

Perennial Weeds. The long resting periods before the cotton and dura crops, shown to be necessary for good yields in the Gezira Scheme, are themselves of value in the control of perennial weeds; for not only is weed-growth less when the land is dry, but there is also a longer time in which the weeds can be controlled by the various measures devised.

The most troublesome perennial weed is nut grass (*Cyperus rotundus* Linn., Arabic: 'se'id'), and, where the growth of this weed is widespread, crop yields are severely reduced. Nut grass grows extensively not only in the Gezira area but also in the Gash Delta, and is common in many parts of Africa. When work on nut grass started in the Sudan no swift means of control was known either in the Sudan or elsewhere. Its control was particularly urgent in the Gezira, for, on badly infected land, yields suffered so acutely that these areas became a liability. Because of the severe stunting of crops that followed, the spread of nut grass might well have jeopardized the prosperity of much of the area. Ineffective attempts had been made at the Gezira Research Farm to poison the weed by spraying, but the crops themselves suffered severely from the effects of the treatments. Hoeing with a hand-tool and ploughing by bulls merely reduced the foliage for a few days or weeks, the vigour of the weed remaining unimpaired. F. W. Andrews, when confronted

(a)

(b)

FIG. 192 (a) and (b). (a) Close-spaced and (b) wide-spaced dura of the variety Dwarf Hegari, in the dura four-factor experiment. The yields of grain per feddan in the two spacings were similar (v. FIG. 191) (*photos by F. Crowther*).

FIG. 193. Dwarf Hegari dura on the Gezira Research Farm, 7 Nov. 1942 (*photo F. Crowther*).

FIG. 194. Feterita dura is one of the most popular varieties in the Gezira (*photo taken on the Gezira Research Farm by F. Crowther, 7 Nov. 1942*).

with this problem, decided that effective control was impossible without a preliminary study of the life-history of the plant.

The underground structure of nut grass is made up of roots and tubers, the tubers being interconnected by rhizomes, i.e. underground stems. When these tubers are planted they develop first of all extensive roots and then a rosette of leaves out of the centre of which grow characteristic flower-stalks which ultimately produce seed. The weed can spread both by seed and by tubers, but the latter are mostly responsible for spread in the Gezira commercial area. Andrews, in 1937, noted from tubers planted in tins, that, where the plants grew unchecked, additional tubers were eventually formed; but that, if the aerial growth was cut at ground level every 3 or 4 days, no new tubers were produced, the plants evidently becoming weakened by the continuous hoeing. Theoretically, therefore, frequent hoeing should be an effective check, but in practice it proved impossible to carry out the hoeing frequently enough. Andrews then examined the weed growing in the field and dug pits 1 metre square on infected soil, separating the tubers from the soil in successive layers. The distribution of the tubers with depth is shown in the following data giving the percentage of the total number of tubers present in each 3-in. step.

	Pits				
Depth (*in.*)	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)
0–3	59·2	75·8	75·4	30·7	16·4
3–6	31·7	22·5	22·3	56·3	37·0
6–9	8·2	1·6	1·7	10·3	23·1
9–12	0·9	..	0·6	2·7	13·7
12–15	..	..	..	0·1	6·9
15–18	..	..	..	..	2·5
18–21	..	..	..	..	0·5
21–24	..	..	..	..	0·1
24–27	..	..	..	..	..

Details of Pits:
(*a*) 9 pits: Gezira Research Farm; June, July 1937.
(*b*) 2 pits: low-lying, waterlogged land; Aug. 1937.
(*c*) 2 pits: cultivated land adjacent to (*b*); Aug. 1937.
(*d*) 6 pits: Gezira Research Farm; Jan. 1938.
(*e*) 6 pits: river silt; Jan. 1938.

The pits were excavated at different times of year and on both irrigated and river soil. The table shows that at the Gezira Research Farm most tubers occurred in the top 6 inches of soil, and that they were rarely found below 12 inches. Among the different pits, the more permeable the soil the lower down the tubers were found; in river soil they were often found to a depth of 24 inches. A typical distribution of nut grass below ground level in soil at the Gezira Research Farm is shown diagrammatically in Fig. 195, which marks the position of tubers, rhizomes, and roots.

Andrews found that, though the tubers were confined to the top foot of soil, the roots extended to a depth of 54 inches, where they were able to tap the less dry soil-layers. The determinations of soil-moisture, made after an uncultivated period of 8 months, and included on the left side

of Fig. 195, show that, although the top foot dried out to less than 10 per cent. moisture, below the second foot the moisture never fell below 20 per cent.—a fact noted in the previous section on soil research. Hence, although the surface soil of resting land dries out sufficiently to hasten the maturation and death of annual weeds, the loss of moisture lower down is not sufficient to destroy the nut grass. Andrews collected tubers from

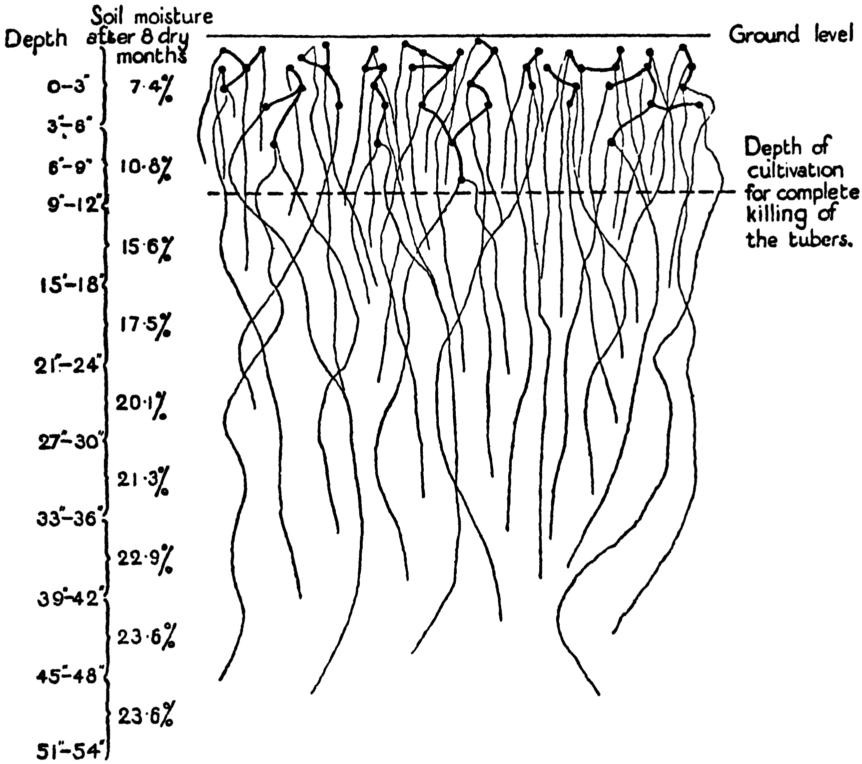


FIG. 195. Diagrammatic sketch illustrating the typical arrangement of the nut grass tubers, rhizomes, and roots in the soil of the Gezira Research Farm. The heavy black dots represent tubers, the thick lines rhizomes, and the thin lines roots. In other parts of the Gezira Scheme tubers are found also at a slightly greater depth. (F. W. Andrews, *Emp. J. Exp. Agr.*).

his pits, and, after removing roots and rhizomes, planted the tubers in soils of varying moisture-content, testing their viability after intervals of 3 and 5 weeks. His results were:

Soil-moisture (percentage)	*3 weeks' interval (number viable out of total of 9)*	*5 weeks' interval (number viable out of total of 6)*
5	0	1?
11	1	0
16	7	1
20	8	4
22	8	6

A moisture-content of 20 per cent. was sufficient to keep the tubers alive for long periods, but in soils with less than 16 per cent. moisture, tubers devoid of roots died within a few weeks. Evidently in the field the deep root-system enables the plant to draw on water even in the absence of rain or irrigation, and so to sustain its tubers.

This conclusion immediately indicated a possible means of control, viz. deep ploughing to sever the roots below the lowest tubers, thus cutting off their underground water-supply. A first trial was carried out in March 1938 with very successful results. Whereas nut grass persisted in the absence of deep ploughing, the ploughed land developed very little nut grass when it was brought under cotton. The result was so encouraging that the Sudan Plantations Syndicate Ltd. experimented with this method of control on 1,400 feddans, using a special cultivator. Andrews, examining the area, found the average depth of ploughing to have been 10 inches and the effect on the viability of the tubers to have been as follows:

Tubers from twenty 1-metre squares

Depth	*Total tubers*	*Viable tubers*	*Percentage viability*
Soil disturbed by ploughing	2,754	15	0·5
Undisturbed soil between ploughed layer and 12 in.	370	106	28·7
Undisturbed soil 12 to 15 in. . . .	139	42	30·2

More than 80 per cent. of the total tubers were in the layer disturbed by ploughing, and of those 99·5 per cent. were dead. Further extensive trials again proved successful, but deep-ploughing of the heavy Gezira soil is difficult and costly. With the standard 60-b.h.p. cable-operated Diesel engine to draw a large cultivator with 12-inch overlapping tines, it was unusual in a single operation for the plough to cut deeper than 4 inches. Therefore it was found necessary to do the deep ploughing in two operations, the first with small tine-points to get depth, and the second with large tine-points to cut all roots and rhizomes. Further increase in the area ploughed for nut grass was stopped by the war.

As a result of this work a method of control of nut grass has been devised. The degree of success attending its use depends upon the depth of ploughing attained in practice—for the agricultural engineer a problem of great difficulty in view of the heavy Gezira soil and the occurrence of tubers at, or even below, a depth of 12 inches. Complete eradication of the weed cannot be expected unless an implement can be designed whose tines cut deeper than the deepest tuber, but a large measure of control is effected with less deep ploughing. It was found that the deep ploughing so far practised conferred immense benefit on the next crop but that the weed revived in the following years from the few tubers remaining in the undisturbed ground, especially when irrigated crops were grown in successive seasons, as in the existing 8-year rotation when 'lubia' follows dura, or where the ground became waterlogged. Pending the development of still better methods of deep ploughing it is necessary

to investigate the conditions under which the existing implement can be used to best effect, and whether the ploughing can be supplemented by other measures.

Annual Weeds on Resting Land. It is customary in the Gezira Scheme to allow annual weeds on the uncropped land to grow unchecked, except for grazing, since all labour available during the rains is usually needed for the sowing and cleaning of crops. Each year after the rains of July and August a carpet of weeds germinates on the resting lands, which later develops into a thick bushy mass, the amount of growth depending upon the rainfall and condition of the soil. As the land gradually dries after the rains, the weeds ripen, shrivel, and are ultimately buried when the land is ploughed before cotton-sowing. Resting land thus resembles the 'return to bush' in shifting cultivation for rain-grown crops of Africa and the resting field of the medieval three-field system, rather than the modern cleaning fallow of western Europe and the dry-farming areas.[1]

Recent experiments by Crowther have demonstrated that the destruction by hand-hoe of the weeds growing on resting land, while they are still small, can lead to large increases in the yield of the cotton sown on such land 12 months later. In the first experiment, made in 1939, weeds on some plots were hoed in late August and on others were allowed to ripen without interference. The yields of cotton grown on this land in 1940–1 were:

	Yield of cotton (kantars per feddan)
Resting land unhoed . . .	4·31
Resting land hoed . . .	6·18
Increase from hoeing . .	1·87 or 43 per cent.

This was a remarkable increase from so simple an operation as hand-hoeing. It was larger than that usually obtained from nitrogenous fertilizer. But in 1939 the rains were heavier, and weed-growth more plentiful than usual, and control of weeds in that year would, therefore, tend to show larger differences than in one of normal or scanty rainfall.

Observations revealed that the hoeing of weeds on the resting land was followed a few days later by a rapid increase in soil nitrates, the nitrate accumulation persisting on the hoed plots until the following year. Moreover, as a result of the hoeing, soil-moisture also was higher, water being conserved at depths of 6 to 24 inches throughout the following 10 months until the cotton crop was irrigated. This demonstrates that, even under the intense heat and desiccation of the northern Sudan, below the top 6-inch layer of soil, moisture is lost mainly by the roots, either of crops or of weeds, rather than directly by evaporation from the soil.

Later experiments showed that there was benefit to cotton where weed-growth was drastically controlled throughout the rainy season. Although interpretations are still largely speculative, there are indications that weeds, if allowed to grow unchecked on the resting land, absorb considerable quantities of nitrogen at the expense of the following cotton. Also,

[1] The farmers of Pliny's time also had cleaning in mind. See footnote on p. 6.—*Editor.*

through the drying effect of the weeds, the moist periods of weedy resting land are curtailed, with, presumably, less opportunity for activity of the micro-organisms which add to the supplies of soil nitrogen. This consideration suggested that irrigation of the resting land to simulate prolongation of the rains, if combined with weed-control, might lead to even greater cotton yields; and the following results were obtained in the 1942–3 season:

Yields of Cotton (kantars per feddan)

Resting land	*Resting land*		*Increase from hoeing*
	Not hoed	*Hoed, 1941*	
Not irrigated	5·68	6·68	+1·00
Irrigated, Aug.–Sept. 1941 .	5·26	6·85	+1·59
Irrigated, Aug.–Oct. 1941 . .	4·94	7·37	+2·43

Where the resting land was kept free of weeds and also irrigated, yields were increased by 1·69 kantars per feddan over those of the dry, unhoed land, an increase made up of 1·00 kantar per feddan from hoeing, and 0·69 from irrigation. The increase from hoeing irrigated resting land was even greater when the yields were compared against similarly irrigated land where the weeds were allowed to grow unchecked. These irrigated but unhoed plots gave the lowest yields of all treatments, presumably because the soil was more exhausted by the heavier weed-growth following irrigation than on the dry land where the weed-growth was checked by drought. Incidentally, these improved yields following moist, instead of dry, resting land, resemble those described earlier when dura followed on plots where the cotton had been pulled early and the land subsequently irrigated.

In general, it appears that more attention should be given to resting land and especially to its behaviour during the rains, for this can affect profoundly the growth of the following crop. The investigations are still in their early stages, but experiments conducted by the Sudan Plantations Syndicate Ltd. on the hoeing of 2,580 feddans of resting land which came under cotton in 1942–3, distributed over all blocks of the Scheme, gave the following results:

	Yield of cotton (kantars per feddan)
Mean yield of 1,130 feddans unhoed . .	4·99
Mean yield of 1,450 feddans hoed . . .	5·30
Increase from hoeing	0·31 or 6 per cent.

The average increase was 0·31 kantars per feddan, but there was considerable variation between blocks, the increases being in some cases as large as in the experiments described and in others, nil.

Future work will examine how the effect of hoeing weeds on the resting land varies in relation to rainfall, type of soil, and botanical composition of the weed-growth. Clearly such hoeing reduces the amount of grazing, and the value of grazing lost through hoeing of resting land must be

assessed against the cost of growing crops such as legumes to replace the weeds for grazing purposes. Finally, hoeing a large area during August and September is almost impossible by hand-labour, which is occupied with sowing and cleaning crops, and it will be necessary to develop bull and tractor implements for this work. When these initial difficulties have been overcome the hoeing of the land before crops may become the routine of the Gezira Scheme, with, as a result, considerable improvement in yields. The most recent indications suggest that dura as well as cotton benefits by hoeing of the preceding resting land in the present eight-year rotation.

Weeds in Canals. A problem which grows more urgent the longer an irrigation scheme continues is the increasing growth of weeds in the canals (v. Fig. 196). When newly dug, the canals are clean, but as the years advance they become more and more weedy, with both floating weeds and those which grow along the banks in shallow water. Such weeds not only impede the flow of water but may also impair the health of the cultivators by encouraging the breeding of mosquitoes and the spread of bilharzia.

In 1937, at the request of both the Sudan Irrigation Department and the Sudan Medical Service, Andrews began investigations on the control of water-plants. In his survey of all the canals of the Gezira Scheme he identified 27 species, of which 10 were important. Studying the control of such weeds he found that fixed weeds growing along the banks did not present great difficulty since they could be hoed and their spread by seeding thereby avoided. Weeds whose tops float in the water (Fig. 196), on the other hand, could not be so simply destroyed. If the canals were allowed to dry out, vegetative growth was greatly checked, but the few months when such drying-out is possible in the Gezira, April to mid-July, proved by experiment to be inadequate for the control of rooted weeds. The tops died, but seeds, as well as roots and underground stems, enabled the weeds to survive. The available poisons were unsuitable, being a danger to man and beast, and were, in any case, ineffective in a flowing stream.

The work revealed no easy method of control and indicated that the best results were likely to accrue from the regular cleaning of weeds to weaken vegetative growth and reduce seeding. To test this conclusion Andrews experimented with different kinds of rakes and, in co-operation with the Irrigation Department in 1940, made a large-scale attempt to control weeds in the Hag Abdalla division. A system of regular patrols was introduced, the interval between patrols being adjusted to inhibit the seeding of the weeds. One man with a rake was allotted the task of clearing 1½ km. of canal per day, but the distance was reduced where weeds were especially plentiful. In some cases the rakes were used from the banks, in others the men walked along the bed of the canals, dragging their rakes behind them. The essence of the plan was regularity, the canals being cleaned by rotation.

The results proved very satisfactory, and the annual costs for clearing floating weeds in the Hag Abdalla subdivision have been reduced from £E469 in 1940 to £E210 in 1942. Permanent freedom from weeds cannot, however, be expected, since reinfection occurs from the Sennar

FIG. 196. Floating weeds in a Gezira canal.

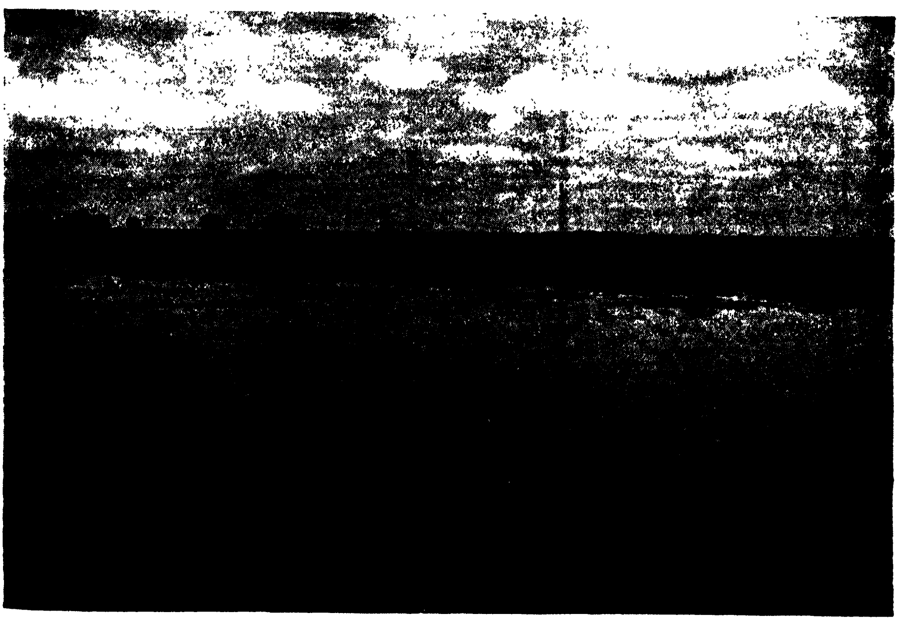


FIG. 197. Young rain dura the day after a moderately heavy storm (grown adjacent to the Gezira Research Farm). The photograph is taken from one of the earth banks 'terūs' which impound the water (*photo F. Crowther*).

Reservoir. The problem has now passed beyond the experimental stage. The solution is practicable on a large scale, and there appears no reason why, so long as it is used consistently, canal weeds need be troublesome in the Gezira.

RAIN-GROWN CROPS

The Gezira

The rainfall at Khartoum averages only 6 to 7 inches[1] a year, but southwards it increases rapidly, Wad Medani, only 108 miles away, receiving 16 inches of rain, or about $2\frac{1}{2}$ times as much as Khartoum. This is sufficient for dura-growing, and even before the advent of artificial irrigation to part of the Gezira the area was known as the granary of the Sudan. Dura, the only rain crop grown there extensively, is usually sown on the same land year after year.

Experimental work on crop management in the Gezira has of necessity centred around the many new problems arising from the introduction of artificial irrigation, but in 1942 a beginning was made on typical rainland, with its system of earth banks ('terūs'), adjacent to the Gezira Research Farm but outside the irrigated tract (v. Figs. 107 and 197). As an extension of the work on the hoeing of annual weeds on resting land, already described, attempts are being made to apply methods of dry-farming to these areas of light rainfall. The purpose is to discover whether, by growing dura crops on any one piece of land in alternate years only and hoeing the weeds in the intervening uncropped year to conserve moisture, it is possible, through this additional moisture, to bring good crops to maturity. No results are yet available, but the experiment is mentioned because of its possible application to cultivation on the edge of the regular zones of rain-cropping.

Experiments by Crowther on the spacing of dura (Dwarf Feterita, Manāgil strain), and on the importance of weed-control among the growing crop, each from a single season but well replicated, gave the following results:

Yields of Dura

	Yields (rotls per feddan, air-dry)		Hoeing weeds	Yields (rotls per feddan, air-dry)	
Spacing	*Heads*	*Straw*	*Hoeing*	*Heads*	*Straw*
Very close (64 cm. × 64 cm.)	490	809	Not hoed	189	252
Close (78 cm. × 78 cm.)	577	809	Hoed from sowing (23 July)	397	487
Normal (90 cm. × 90 cm.)	614	752	Hoed mid-Aug. onwards	393	516
Wide (127 cm. × 127 cm.)	706	700	Hoed early Sept. onwards	257	428

[1] 1 inch = 24·5 mm.

The normal spacing of rain-dura around Wad Medani is 90 cm. × 90 cm., and the results indicate that a still wider spacing would produce more heads, and a still closer spacing more straw, per feddan. Since both products are valuable either as grain or fodder, the normal spacing probably represents the 'happy medium' for the dual purpose. As expected, hoeing is not urgent while the weeds are small, but a delay in hoeing may cause a large reduction in both grain and straw.

Nuba Mountains

South of the Gezira, where the rainfall is from 20 to 30 inches, the variety of rain-cropping is widened by the inclusion of sesame and ground-nuts, and by the introduction into the Nuba Mountains, south-west of the Gezira, of the valuable cash crop, cotton. For more than 15 years much effort has been expended by Inspectors of Agriculture[1] under difficulties, not the least of which is poor communications during the rains—the busiest time in the experiments. The wide seasonal variation in amount and distribution of rainfall makes it necessary to repeat experiments for many years before reliable results can be obtained. Also experience gained in the Gezira, the only area of the Sudan where intensive experimental work has been done, is of little help in elucidating problems of crop management in such districts as the Nuba Mountains. In the Gezira, crops are grown by irrigation on a highly impermeable soil where erosion is virtually absent: in the Nuba Mountains there is no irrigation of crops, rainfall is much heavier and the soil types more varied, and erosion can become acute if the soil is left unprotected. In the Nuba Mountains, as in the other rain areas of the Sudan and in other African countries, the final design into which European and native methods can be interwoven to create a permanent system of agriculture has yet to be evolved.

Information has been obtained on the best sowing-date both for cotton and for sesame (*Sesamum indicum* Linn.) and on the spacing of cotton. The yields (kantars per feddan for cotton, rotls per feddan for sesame) of these experiments conducted at one or more of the four centres Kadugli, Talodi, Dilling, and Um Berembeita, are summarized in the following table:

Cotton: Sowing-date and Spacing

(a) Sowing-date		*(b) Spacing*			
Um Berembeita		*Talodi*		*Um Berembeita*	
	Yield (av. of 2 years)		*Yield (av. of 2 years)*		*Yield (av. of 2 years)*
22 June	2·62	50 cm. × 50 cm.	3·61	25 cm. × 25 cm.	1·29
9 July	2·41	50 cm. × 75 cm.	2·83	50 cm. × 50 cm.	2·34
31 July	1·74	50 cm. × 100 cm.	2·80	75 cm. × 75 cm.	2·51
15 Aug.	1·55	100 cm. × 100 cm.	2·42	100 cm. × 100 cm.	2·18

[1] Especially G. F. March, J. R. Burnett, R. T. Paterson, W. A. Porter, H. A. Graves, L. E. James, E. S. Colman, and J. W. Hewison.

Sesame: Sowing-date

Kadugli		*Dilling*		*Talodi*	
	Yield (av. of 4 years)		*Yield (av. of 4 years)*		*Yield (av. of 2 years)*
Mid-June .	478	1 July .	317	15 July .	321
Early July .	389	8 July .	323	25 July .	245
Mid-July .	309	15 July .	255	4 Aug. .	176
Early Aug. .	286	23 July .	164	14 Aug. .	113
Mid-Aug. .	261	30 July .	142	..	..

Experience with the commercial crop of cotton had established that the earliest sowings, after the rains had broken, gave the highest yield, and this was confirmed in experiments. The optimum spacing for cotton appears to be about 50 cm. × 50 cm., or about 4 holes per sq. m., but a slightly wider spacing may be preferable in the Um Berembeita district. With sesame too the earliest sowings gave the highest yields, and this has been demonstrated at three different centres.

One experiment on the vexed question of the place of ploughing in native agriculture merits description, since it revealed large increases in yield when poor land was ploughed. It was started by E. S. Colman in 1936 at Talodi, on virgin soil which subsequently was cropped annually with cotton for purposes of the experiment. The average yields of the first three years were:

Cotton Yields (kantars per feddan)

	Poor soil	*Good soil*
Unploughed soil . .	1·69	2·91
Ploughed soil . . .	2·45	3·20
Increase from ploughing .	+0·76	+0·29

Each season the ploughed land gave higher yields than the unploughed. On poor soil higher up the slope the average increase from ploughing was 45 per cent.; but on good soil lower down it was 10 per cent. O. W. Snow found that the poor soil was lighter in composition and cracked less, the clay-contents in the top 6 feet of soil for the poor and good soils being respectively 46 and 66 per cent. This suggests that ploughing increased the water uptake of the poor soil by loosening the surface. On the heavier soil the advantage was less because cracks enabled water to penetrate into the unploughed land.

The cultivators normally grow cotton every year on the same land until the yields fall considerably and only then shift their cultivation to new sites. G. F. March, to investigate the importance of rotation of crops under these conditions, started an experiment at Talodi in 1928, and the yields of this and of a later experiment started at Kadugli in 1936 are summarized below:

Kadugli			Talodi		
	Yield (av. of 6 years)			Yield (av. of 15 years)	
Rotation	*Kantars per feddan*	*Percentage*	*Rotation*	*Kantars per feddan*	*Percentage*
Continuous cotton	2·39	100	Continuous cotton	2·93	100
Cotton–fallow	2·16	90	Cotton–cotton–fallow	3·19	109
Cotton–dura	2·22	93	Cotton–dura–fallow	3·05	104
Cotton–dura–'lubia'	2·75	115	Cotton–sesame–fallow	3·24	110
Cotton–dura–½ sesame and ½ 'lubia'	2·66	111	Cotton–fallow–½ ground-nuts and ½ 'lubia'	3·56	121

At Kadugli the yields of continuous cotton are below those rotations which include a legume; but they, as well as those of a two-year cotton–dura rotation, are all above the cotton–fallow, where the weeds developing on the fallowed land were hoed occasionally during the rains. This result is a reversal of the findings for irrigated crops in the Gezira Scheme and may be ascribed to the differences between the two regions in type of soil and liability to soil erosion. At Talodi, sesame compares favourably with dura as a crop to follow cotton; and, as at Kadugli but in contrast to the Gezira Scheme, a legume is of value immediately before cotton. Such differences between the irrigated and rain areas are not confined to rotations. Thus, for instance, in the Nuba Mountains the earliest sown cotton gives the best yield, whereas in the Gezira the highest yields are from sowings made in the middle period. This disagreement, as stressed earlier, renders experimental work more difficult, and totally different approaches to the two sets of problems are required.

This difference in approach is illustrated by intercropping experiments which have no parallel in those described for irrigated areas. In many parts of Africa cultivators grow two crops simultaneously on the same land. When a new crop such as cotton is introduced, with its need of clean cultivation and therefore its liability to cause soil-erosion, the practice of sowing a second crop with it holds out possibilities of benefit to crop yields and soil.

In an experiment the results of which are shown in the table on the following page, cotton was sown at a spacing of 90 cm. × 75 cm. between holes, and a row of ground-nuts alternated with a row of cotton. The highest yields of cotton were obtained with no intersowing of ground-nuts (treatment 1), but a reasonable yield of ground-nuts as well could be obtained from the same land at the same time, at the cost of only a moderate reduction in cotton yields (treatment 2). The relative amounts

of yield from the two crops can be adjusted by changing the sowing-dates; the yields of both crops are highest with the earliest sowings, but relatively more ground-nuts can be obtained by sowing them first and delaying the cotton slightly. If both are sown late the cotton does not suffer greatly but the ground-nut crop is a failure. Other legumes have been tried among cotton, but usually their climbing habit renders them less suitable than ground-nuts for intercropping. Here then is a promising line of investigation, well suited to peasant cultivation, where a cash crop and a food crop can be grown simultaneously and the land neither exhausted nor exposed to severe erosion. The next step is to include intercropping in rotation experiments to compare the residual effects with those of crops sown separately. Sir Daniel Hall,[1] writing on the problem of rotation, concluded: 'The first necessity in these agricultural communities of Africa is a change from shifting cultivation to fixed agriculture, to a recuperative system of farming which will maintain cultivation indefinitely on the same land.' Thus, with the likelihood of increased population, work on the cropping rotation of fixed areas must proceed side by side with the problems of shifting cultivation.

Intercropping Experiments (average of 2 years)[2]

	Yields (rotls per feddan)	
	Cotton	Ground-nuts
1. Cotton alone	749	. .
2. Cotton and ground-nuts sown same date as (1)	534	591
3. Ground-nuts sown same date as (1), cotton 14 days later	461	688
4. Cotton and ground-nuts both sown 14 days later than (1)	650	167
5. Cotton sown 14 days later and ground-nuts 28 days later than (1)	655	93

Shifting cultivation has been carried out with great skill by the inhabitants of the Nuba Mountains, and of similar belts farther east. In most parts of Africa the burning of the bush-growth of grass usually takes place during the dry season, either to provide green shoots for grazing or to clean land for cropping during the following rains. In the Nuba Mountains growth of vegetation, mostly grasses, during the rains limits the areas which can be cropped, and hand-labour for hoeing is so inadequate that the cultivators have developed the practice of burning the grasses (called 'harīq', the Arabic for 'burning') after the rains have started, instead of during the dry season, thereby utilizing the flames fed by the mature grass to destroy the growth of young grass. For 'harīq' to be successful the mat of old grass must burn freely, and it is on this basis that the areas to be burnt are selected; certain types of grass are better for burning than others, and these must have reached a sufficient degree of spread.

[1] *The Improvement of Native Agriculture*, Oxford University Press, 1936.
[2] This experiment was conducted by R. T. Paterson at Kadugli, and similar results were obtained by W. A. Porter at Talodi.

Experimental work on 'harīq' was started in 1939 at Dam Gamad, near Talodi, by W. A. Porter, and in 1940 at Um Berembeita by J. W. Hewison. Although this new work was interrupted by the war, the species of grasses most suitable for burning have been established. By broadcasting seed of these, a mat sufficient for burning was obtained after one year as compared with three or four years by natural regeneration. It remains to be seen whether this single year is long enough for recuperation of the soil where the grasses are grown on old cultivations. Information is needed too on the best crop to precede the resting period and the order of cropping on the newly fired land, for the opinion is that the first crop after firing is inferior to the following one. More fundamentally, it is necessary to examine the whole sequence of changes which follow the regeneration of grasses and their subsequent destruction by fire. Not only is the all-important crumb-structure of the soil restored by a period under grass, but possibly the very heating itself is beneficial to the soil, for T. W. Clouston has obtained large increases in the yields of Gezira crops by firing the surface soil. On the other hand, nitrogen is lost when the grasses are burnt, and that this is undesirable is indicated by the additional yields obtained where a legume was included in the rotation experiments. Waiting for the new growth of grass at the beginning of the season leads to some delay in sowing the first crop after the burning, and a delay in sowing usually causes a reduction in yield. All these and many related subjects, such as the protecting effect of 'harīq' cover against soil erosion, remain for study; meanwhile the use of 'harīq' enables a much larger area of crops to be sown and harvested successfully each year than would be possible if the grasses had to be destroyed by the hoe.[1]

Equatoria

Finally, experiments have been conducted in the extreme south of the Sudan, where the rainfall reaches 60 in. per annum and is distributed over a longer period than farther north. Hitherto most work has been concentrated on the introduction of new plants and on improving the varieties of the existing food crops and of cotton; and this is described later.

An intercropping experiment comparable to that in the Nuba Mountains, made by A. P. Milne at Maridi, compared cotton grown alone with cotton intersown with ground-nuts. The yields, averaged over two years, were:

	Yields	
	Cotton (kantars per feddan)	*Ground-nuts (rotls per feddan)*
Cotton, spaced at 75 cm. × 100 cm.:		
(*a*) grown alone	4·05	..
(*b*) alternating with 2 rows of ground-nuts	3·57	1,579
Cotton, spaced at 75 cm. × 50 cm.:		
(*a*) grown alone	4·46	..
(*b*) alternating with 1 row of ground-nuts	4·28	1,298

[1] For further discussion of 'harīq' cultivation see pp. 292–3.

Here, as in the Nuba Mountains, a combination of the two crops has definite advantages, for alternate rows, both sown early, gave good yields of both crops. A less successful result was that obtained on intersowing sesame with 'telebun' (*Eleusine coracana* Gaert.; finger millet), a common native practice. The average yields of these experiments were:

	Yields (rotls per feddan)	
	Sesame	*'Telebun'*
Sesame grown alone . .	385	..
Sesame grown with 'telebun'.	85	1,267
'Telebun' grown alone . .	..	1,553

Under the conditions of sowing-date, &c., in the experiment, intersowing of these two crops was unsuccessful, competition between them greatly reducing the yields of the sesame, with considerable reduction also in the yield of the 'telebun'. Since both are exhausting crops it would be interesting to examine the effect of replacing one of them by a legume. Mixed cropping being a common practice as an insurance against total failure of the crops, many more experiments on these lines are necessary.

One other result on crop management stands out clearly, viz. the importance of early sowing of cotton here as in the Nuba Mountains. At Maridi the average results of five seasons' experiments are as follows:

	Yields of cotton	
	Kantars per feddan	*Percentage*
Sown 15 May . .	2·49	100
Sown 15 June . .	1·73	69
Sown 15 July . .	1·24	50

The earliest sowing tried gave the highest yield and yields fell sharply with delay in sowing, July sowings giving only half the yield of May sowings. Recently at Kagelu H. Ferguson has obtained large increases in yield with sowings as early as April, and has found that the crop suffered less from pest damage than when sown later. These results, coupled with others of his, where good yields were obtained when cotton was broadcast on undug grassland and then buried by digging under the grass cover, suggest that certain radical changes in husbandry may lead to considerable improvement in yield, and may make the cotton crop more popular with the cultivators.

Experiments have also been started on the best means of conserving the fertility and physical condition of the soil, especially in the non-cattle areas; but the work on crop management in Equatoria, as in the other rain-crop areas of the Sudan, is only in its infancy, and a vast number of problems still await solution.

III. ANNUAL VARIATION IN THE COTTON YIELD OF THE GEZIRA SCHEME

The amount of cotton produced each year in the Gezira Scheme not only affects the prosperity of its inhabitants but, by its contribution to revenue, helps to finance both directly and indirectly the development of the entire Sudan; directly in the share which the Government takes of the receipts of the exported crop, and indirectly through, for example, increased freight on the railways and the greater spending power of the cultivators. Large fluctuations in yield may have far-reaching repercussions, especially when low yields synchronize with low prices. Discovery of the causes of the year-to-year differences in the yield of cotton is therefore of considerable importance.

The commonest cause of yield fluctuation in Africa is variation in annual rainfall, drought leading to famine being no rare experience. Where rainfall is scanty and water can be supplied by irrigation, the usual source of fluctuation is eliminated and consistent yields are anticipated. Such is the case in Egypt where, despite the vagaries of the rainfall in East Africa, the Nile flow is assured, and by irrigation alone crops are produced with a probably unique constancy of yield. By contrast, in the Sudan Gezira there is no such regularity of yield. Moreover, during 3 months of each year the rainfall is relatively heavy for an irrigation scheme, and this rainfall, unpredictable in amount and distribution and falling on the impermeable soil, not only creates difficulty in the actual growing of the crop but introduces a factor of extreme variability.

The annual cotton yields per feddan of the Gezira are shown opposite p. 786, and they are given diagrammatically up to 1942–3 in Fig. 198. For four of the five years ending with season 1933–4, the yields per feddan each year were less than half the yields of the early years. This circumstance at the time appeared all the more alarming when the trend of the yields was examined, for the low yields formed part of a definite progressive decline in yield from the start of the Scheme, interrupted only by isolated years, and reaching its lowest ebb in the crops sown in 1930, 1932, and 1933. Great concern for the future of the Scheme was aroused, and its critics saw in the decline the logical outcome of failure to drain the Gezira soil and so prevent the deterioration presumed to be inevitable with the introduction of artificial irrigation to a soil already possessing large quantities of sodium salts. It has been shown that the evidence from soil investigations was against this view of deterioration, a conclusion supported by the results of a statistical examination of yield data in relation to rainfall which is described below.

Relation of Yield to Rainfall

The cotton yields of the Gezira Scheme are, for a commercial area, unusually amenable to statistical analysis because the weight of cotton from each 10 feddans is recorded separately by the Sudan Plantations Syndicate Ltd. as part of the system of payments to the tenants, and the

yields per feddan for every year, over the entire scheme, are available from the opening of the first pump-scheme at Taiyiba in 1911. Since 1933, however, big changes in agricultural practice have been introduced, and these complicate any analysis of the later period.

1911 to 1933. The first analysis of yield data in relation to rainfall was made by E. M. Crowther of the Rothamsted Experimental Station who, in 1925–6, worked for 6 months in the Gezira. He divided the annual

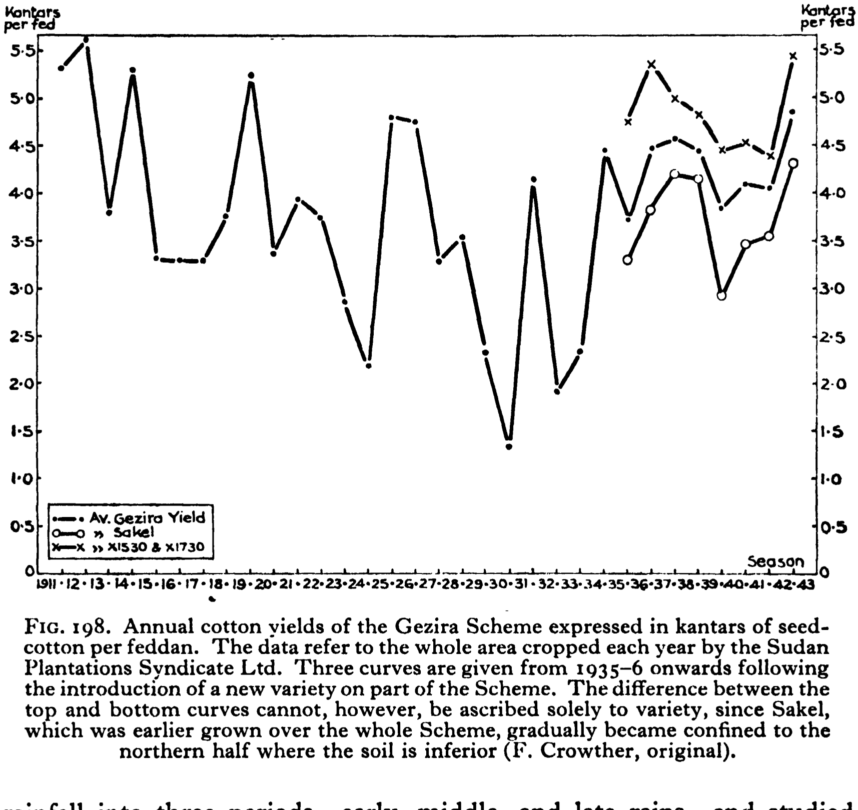


FIG. 198. Annual cotton yields of the Gezira Scheme expressed in kantars of seed-cotton per feddan. The data refer to the whole area cropped each year by the Sudan Plantations Syndicate Ltd. Three curves are given from 1935–6 onwards following the introduction of a new variety on part of the Scheme. The difference between the top and bottom curves cannot, however, be ascribed solely to variety, since Sakel, which was earlier grown over the whole Scheme, gradually became confined to the northern half where the soil is inferior (F. Crowther, original).

rainfall into three periods—early, middle, and late rains—and studied these in relation to the cotton yields of the Gezira Research Farm and also of certain parts of the commercial area, such as Taiyiba and Barakat which were but little affected by the gradual extension of the scheme. He discovered that heavy early rainfall, in May–June, had a marked and previously unsuspected depressing effect on the yield of cotton, although the crop was not sown until 2 to 3 months afterwards. His early results were later confirmed in 1933 when, in conjunction with F. Crowther, he made a second analysis using the additional data from the years 1925–33 and including the rainfall of the year previous to sowing. Abnormally heavy rainfall at any time was found to be associated with abnormally low cotton yields. Typical results of this latter analysis are summarized in the table below to show the average effect on cotton yield of (*a*) 100 mm. (about 4 inches) of rainfall and (*b*) an amount equal to

the normal rainfall of the period, for each of the four periods of rainfall mentioned:

Period of rainfall	Proportion of total rainfall (percentage)	Reduction in cotton yield in kantars per feddan	
		(a) By 100 mm. rainfall	(b) By normal amount of rainfall
Early (up to end of June) .	12	1·3	0·8
Middle (July–Aug.) . .	70	0·4	1·2
Later (after end of Aug.) .	18	1·1	0·7
Previous year (total) . .	..	0·6	2·6

The yield data for this table were obtained from an area of 480 feddans at Taiyiba for the years 1917 to 1931, chosen for their uniform cropping. In all periods rainfall was found to depress the yield, even when it fell before the sowing of the crop in August. As E. M. Crowther had discovered, unit amount of rainfall was most harmful if it fell in May–June of the sowing year, the depression being three times as great as that from the same amount of rain falling in July–August. Moreover, heavy rainfall in the year previous to the sowing year depressed yield; and these depressing effects were cumulative, the crop in the second of two successive wet years suffering from the combined effects of previous and present years' rainfall.

Besides this depressing effect of unit amount of rainfall, account had to be taken of the distribution of rainfall within the season, for normally 70 per cent. of the total falls in July–August, and only 12 per cent. in the early period. The reduction in yield from an amount of rain equal to the normal of each period is included in the table, and this showed the greatest decrease in yield from the 'middle period' and 'previous year's' rainfall.

But even this did not give a clear indication of the relative importance of abnormally heavy rain when it fell at the different times of year, for wide abnormalities occurred much more frequently in the early and late periods than in the middle period. This extra rainfall was allowed for by calculating the 'standard deviation' of rainfall per season, for each period. This showed the year-to-year variation for each rain-period about its mean; the standard deviations were 30 mm. for early, 90 mm. for middle, 50 mm. for late, and 100 mm. for total. Combining these with the reductions per 100 mm. of rain given in the previous table, the effect of these amounts of extra rainfall was about the same in all periods, viz. a loss in yield of about 0·5 kantars per feddan in each of the four periods. Thus, over the years examined, abnormally heavy rain depressed the yield of cotton to about the same extent in whichever period it fell.

The extent to which variations in the yield of the Gezira up to 1933 can be explained in terms of amount and distribution of rainfall is illustrated in Fig. 199, which gives, for the whole Gezira and for specific areas, the actual yields obtained in the field and those calculated from a knowledge of the rainfall data and of the general trend in yield. The agreement between the two sets of curves is remarkably close and strongly supports

the view that, over the years studied, fluctuations in the Gezira yields were primarily a result of fluctuations in rainfall.

The analysis also threw light on the question of the general decline in yields, evident in Fig. 199, during the period of 20 years from the beginning of cotton irrigation. Whereas at Taiyiba the early yields were around

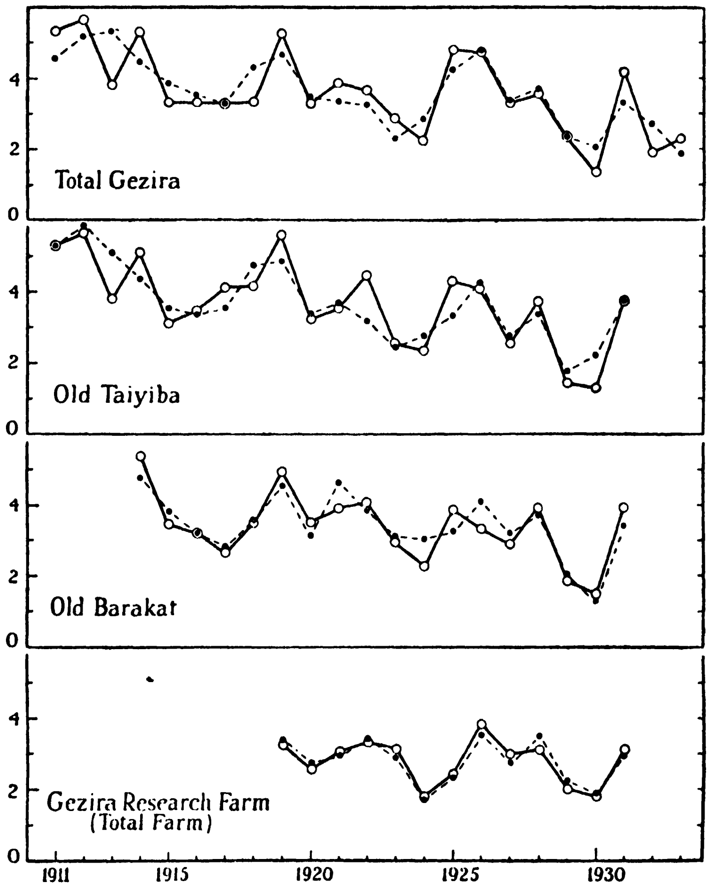


FIG. 199. Comparison of the actual yields in kantars per feddan (—o—o—) from the Gezira Scheme and from special areas within it, with corresponding yields calculated from the amount of rainfall and the progressive change in yield with time (-•-•-•-•-) (E. M. and F. Crowther, *Proc. Roy. Soc.*).

5·0 kantars per feddan, 20 years later they were only about 2·5 kantars per feddan, or about half the earlier ones. If this progressive decline had continued, the commercial production of cotton would have collapsed within a very few more years. Examination of the rainfall data, however, showed that in the early years of the Scheme rainfall was lighter than towards the end of the period. At Taiyiba, for instance, there had been a progressive increase in rainfall, which, in view of the findings described earlier, might explain a progressive fall in yield. In the analysis, whereas the yield data alone showed a progressive reduction of 0·1 kantars per feddan

each year, when allowance was made for effect of rainfall the progressive reduction was only 0·01 kantars per feddan each year, which was insignificant. There was, therefore, no evidence to support the view that the lowering of yield in the Gezira arose primarily from either exhaustion or deterioration of the soil. Instead, if a succession of years of lighter rain followed that of heavy rainfall, a return to higher yields could be anticipated.

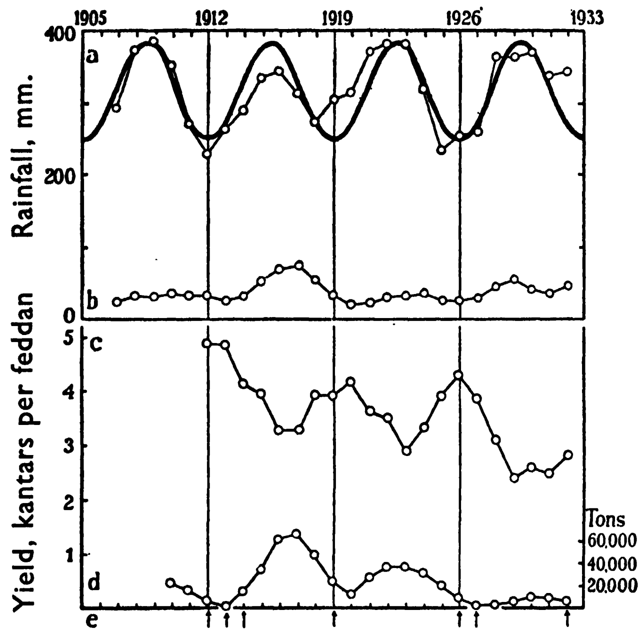


FIG. 200. Yearly values for the (*a*) total rainfall, averaged from five stations in the north-eastern portion of the Gezira, the thick line showing the 7-year periodicity calculated from the data; (*b*) early rainfall (up to June 30) for the same stations as in (*a*); (*c*) cotton yields, in kantars per feddan, for the Gezira Scheme; (*d*) total exports of dura from the Sudan. To reveal any periodicity all are calculated as 3-year overlapping means. For (*d*), dura exports, the arrows (*e*) mark the individual years when exports were below 2,000 tons (E. M. and F. Crowther, *Proc. Roy. Soc.*).

In the course of the examination of the rainfall and yield data, a pronounced periodicity in Gezira rainfall was revealed, wet years tending to recur at intervals of 7 years [Fig. 200 (*a*)]. Of the years for which rainfall records were available, 1905 to 1932, the heaviest rainfall occurred in 1909, 1916, 1923, and 1930. Intervening dry years recurred at similar intervals. The Gezira Scheme, happening to begin in a dry phase of the 7-year cycle, held out unduly rosy prospects of success; on the other hand, the very low yields about 1930 were associated with a peak in rainfall and rendered the picture unduly gloomy. This cycle must not be confused with the one in Pharaoh's dream also associated, through the Nile, with rainfall in the countries to the south of Egypt. The seven fat years were followed by seven lean ones, making a 14-year cycle, not a 7-year one as in the

Gezira. Nor is it a sunspot cycle which, as S. H. Schwabe showed in 1843, tends to be of 11 years.

A 7-year periodicity in the production of food crops had been noted previously, for the Secretary for Economic Development, Sudan Government, wrote in 1932, 'From the records that are available, the periods of food scarcity appear to occur in cycles of six or seven years.' Years in which the Government was compelled to take special measures to meet serious shortage of grain occurred in 1913–14, 1918–19, 1925–6, and 1933, all in troughs of the rainfall curve shown in Fig. 200 (*a*). Since the most important food crop in the Sudan is dura, and most of it is grown on rain, export is possible only in seasons of plenty, that is, of heavy rain. The export curve [v. Fig. 200 (*d*)] reveals a periodicity similar to that of the Gezira rainfall.

1933 to 1943. Since 1933 the 7-year cycle has been less evident than in the previous 30 years and the rainfall of the Gezira, considered as a single unit and represented by the same five rainfall stations as in the early years, has varied within a smaller range, there having been only one very dry and no very wet years. Since 1933 the cotton yields of the whole Gezira also have varied less, as is illustrated in the following table showing the highest and lowest annual yields in each of four cycles of seven years, ending with 1940:

Yield (kantars per feddan)

	1st cycle	*2nd cycle*	*3rd cycle*	*4th cycle*
Highest	5·30	4·80	4·04	4·54
Lowest	3·29	2·21	1·30	3·72
Range	2·01	2·59	2·74	0·82

The range of yield in the last seven years, ending in 1940–1, was less than half that of all previous cycles, and less than one-third that of the second and third cycles. It must not be assumed, however, that constancy of the yields in the last cycle is merely the result of the less variable rainfall during the period, despite the relationship established for the years 1911–33, for recently drastic changes in agricultural practice have been introduced.

The Gezira Scheme is managed as a single large estate and the advantages of this arrangement are manifold. But in this problem of interpreting yield differences, whereas in peasant agriculture change is slow, in a large commercial scheme of this type sudden and sweeping innovations may be adopted which complicate statistical analysis and obscure its interpretation. Thus in 1931, and again in 1934, the rotation of the entire Scheme was changed, in endeavours to prevent the recurrence of the very low yields of 1930–1. In 1931–2 the whole Scheme was sown with fresh seed from Egypt, and at the end of 1932–3 root-pulling was introduced to control leaf curl disease. The average sowing-date was postponed to reduce blackarm damage. The variety X1530 was first grown commercially in 1934–5 in one of the 35 blocks comprising the Scheme, and then in 1935–6, because of its success, was sown exclusively

on 14 blocks including the whole area south of Wad Medani. These changes began to be effective in 1933, and though they did not noticeably interfere with the years covered by the statistical analysis already described, they seriously complicate its extension to later years, for the continuity is lost.

Superficial examination of the yield and rainfall data suggests that years in which rainfall is above normal are no longer associated with the same degree of yield reduction, and that the Gezira crop can now withstand adversity better than formerly. There is some evidence that heavy July rainfall may even be beneficial, but whether or not this altered relationship arises from changes in cultural practices is as yet impossible to determine absolutely. Some of the permanent experiments at the Gezira Research Farm have been maintained on the same rotation and sown always with the Sakel variety, and even the yields of these do not show as close a relationship between rain and yield as formerly. It must therefore be concluded that, though the relationship until 1933 for the whole Gezira and for the separate areas examined was clearly defined, the indications are that subsequently the relation is less close than formerly. Because of the changes in crop management the issue has become confused and cannot be resolved at the present stage by statistical analysis for lack of adequate data to allow of correction for varietal and other factors. Whatever the cause, very low yields with their attendant alarms and uncertainties concerning the prosperity of the country, have up to 1943 been absent for nine consecutive years. Optimism must, however, be tempered with caution in the absence during that period of abnormally wet years; for until a succession of these has again been experienced, it will be unwise to assume that low yields in the Gezira will not recur.

Causes of Annual Fluctuations in Yield

The study of the causes of yield fluctuation has not been confined to the statistical analysis described above. In the early years observers were inclined to predict that an unusually sharp decline in humidity in November presaged a small crop. The discovery that a close relationship existed between yield and rainfall marked an important step forward, for it gave direction to further investigations. Yet the relationship showed only that rain is harmful; it did not reveal the mechanism by which rain operates. Investigation has been rendered difficult by the numerous changes introduced since 1933 which prohibit the reproduction for detailed study of that combination of environment and disease damage which produced the very low yields of seasons like 1930–1.

Fortunately, in 1927–8, M. A. Bailey and A. R. Lambert started an observation plot, Plot 57, at the Gezira Research Farm with the express purpose of investigating the factors responsible for seasonal differences in crop growth and yield. The experiment includes the critical years 1929 to 1933, and has continued with only minor changes up to the present time. All cultural practices are standardized, and sowing-date, variety, and rotation of crops are fixed. Moreover, to assist in the analysis and interpretation of the yield data, detailed records of crop growth and development were started by Lambert and are still continuing.

This experiment has revealed that the crops which produced high yields exhibited especially vigorous vegetative growth early in the season. Although differences in the field only became obvious to the casual observer several months after sowing, detailed measurements revealed seasonal differences very early in the life of the young plant, that is, during the rainy season. In this way the work linked up with the earlier analysis of yield and rainfall.

Searching for seasonal differences in growth Lambert discovered that, as early as seven days after sowing and only three days after the appearance of the plants above ground, the nitrogen-content of the leaves differed sufficiently between seasons to reflect the broad differences in final yield. A low nitrogen-content was usually followed by a low yield, as in 1930–1 and 1932–3, and a high nitrogen-content by a high yield as in more recent years. These results suggested that nitrogen-content of the leaves[1] was probably an index of a soil factor whose intensity, changing from year to year, governed to a considerable extent the differences in final yield.

Associated with the initial differences between seasons in the composition of the leaves were differences in the rate at which the plants grew. These later were reflected, not only in heights and amounts of leaves, but in rate of defoliation, or leaf-shedding. When leaf-shedding was low yields were high and amount of defoliation proved to be an especially reliable indicator of yield. As the season progressed these differences in the rate of crop development accorded more and more closely with those in yield, as is shown in the following table, based on the results of 10 years, and prepared by F. Crowther, who continued the work after Lambert's retirement:

Date	*Observations used*	*Measure of closeness of agreement between developmental data and yield (max. possible 100)*
End of Aug.	Nitrogen within leaves	47·9
,, Sept.	Nitrogen within leaves plus height	65·5
,, Oct.	Height plus defoliation	69·6
,, Nov.	Height plus defoliation	89·3

The closeness of the agreement between the developmental and yield data can be gauged by the percentage of 'sums of squares'—a statistical measure of the variation of yields about their average—which can be explained in terms of seasonal differences in plant development. About half the 'sums of squares' was eliminated when the data for leaf-nitrogen content at the end of August, i.e. shortly after sowing, were taken into account. By the end of September, when differences in plant height also

[1] Most of the nitrogen in a cotton seed is contained in the cotyledons, hence plants growing from seeds rich in nitrogen at first tend to show higher nitrogen-percentages than those from seeds of lower nitrogen content. The relationship discovered by Lambert is, however, quite distinct from any influence of seed quality.

were accounted for, the 'sums of squares' eliminated increased to 65·5 per cent. In a normal year leaf-shedding begins in October; and with plant height as a measure of vegetative vigour, and defoliation as a measure of how long the leaves continue to function actively, the 'sums of squares' eliminated was 69·6 per cent. by the end of October and 89·3 per cent. by the end of November. This result shows that, over the 10 years of the investigation and under the conditions of the experiment, much of the yield difference was determined early in the season, and a great deal by the end of November. Conditions obtaining during the last four months of growth could only have had, therefore, a minor influence on yield.

The yields of this observation plot proved to be highly correlated with those of the surrounding commercial area, and it therefore seemed justifiable to apply these results generally and to conclude that variation in the yield of cotton in the Gezira from year to year is determined to a considerable degree by a soil factor which controls the rate of root-growth and/or of absorption of nitrogen from the soil, and whose varying intensity from year to year is reflected in the crop's development from a very early stage.

The extent to which rain operates on yield through this and other soil factors and through such agencies as diseases, pests, temperature, and air humidity, is a much debated question. Both blackarm and leaf curl can survive the dead season, the one on seedlings and the other on ratoon shoots, and the growth of both seedlings and ratoons is encouraged by heavy rain. Insect pests like thrips and white-flies multiply on the annual weeds which germinate after rain-storms, and the amount and distribution of the rain affect the numbers of insects and their migration to the cotton at the time of the drying of the weeds. Termites become very active when the surface soil is moist and easy to build into their earthen casts; and while, on the one hand, they participate in breaking down crop and weed residues in the soil, on the other, they damage the cotton plants by destroying the roots. Heavy storms in July and August may delay sowing beyond the optimum date and, by encouraging weed-growth on the cotton land, increase competition with the young cotton plants. Heavy rain-storms after sowing can interfere with the germination and growth of the seedlings and can carry blackarm to them and spread it rapidly through the new crop. Destruction of the young roots often occurs when rain falls on newly irrigated land. Rains also encourage the growth of weeds on the resting land, except in low places where prolonged water-logging may inhibit it so that there is less weed-growth than in a dry year. With the onset of the rains, through increase in soil-moisture, the activity of soil micro-organisms on all land, whether cropped or resting, increases rapidly, and with it the complex changes in amount of available soil nitrogen.

The principal agencies whereby rain operates directly on the plants are easily recognized, but far less apparent are those through which the yield of a crop is affected by rain which fell before that crop was sown. E. M. Crowther, in 1926, explaining the correlation he had found, suggested that heavy early rain reduced the supply of available nitrogen in the soil. Later investigators argued that the relationship arose from the heavy nature of

Gezira soil, early rain interfering with the formation or persistence of soil-cracks, the channels of penetration of moisture to the subsoil. The beating effect of heavy rain which, by destroying the crumb-structure of the soil, may interfere with aeration and the penetration of water to the lower soil layers, has also been suggested as the agency. Others have ascribed the entire effect to disease, early rains assisting the survival of blackarm and leaf curl through the dead season. The effect of the previous year's rain has been thought to operate through the increased weed-growth, which not only by seeding creates still more weeds the following year, but also dries out the soil prematurely and locks up nitrogen, which is thus unavailable to the cotton crop.

No single explanation of the yield fluctuations has been found generally acceptable, and the investigations continue. The possibility is not overlooked that the soil of the Gezira may not yet have attained an equilibrium following the radical and complex changes set in motion by the introduction of artificial irrigation and cotton cultivation. This could account for a changing relationship with time and might limit the application of any solution to a few years only. Yet such a solution is of more than academic interest, for with the organization and division of labour within the Gezira Scheme, large and small modifications in agricultural technique can be quickly embodied, and any discovery which mitigates the yield reduction when rainfall is unfavourable is a contribution to the welfare of many thousands of cultivators and to the general prosperity of the Sudan.

IV. MAJOR CROP PESTS

For this section investigations on five major pests of the Sudan crops have been selected for description. These consist of three on irrigated cotton, viz. thrips, pink bollworm, and jassids; one on American cotton, viz. stainer-bug; and one on dura, viz. 'andat' or dura-bug. The account illustrates the varying ways in which such problems are approached and the different means of control discovered. Locusts, because of their widespread ravages and the large amount of work expended on them in the Sudan, have been allotted a chapter to themselves (v. p. 404).

COTTON THRIPS (*Hercothrips* spp.)

Thrips hold an important place in the history of the research work in the Gezira Scheme, because it was largely the anxiety they aroused about the ultimate success of cotton cultivation in the Gezira which led to the opening of the first laboratory at the Gezira Research Farm.

The earliest reports of the Gezira Scheme, from its small-scale beginning at Taiyiba in 1911–12, speak of damage called dry ''asal',[1] which was subsequently recognized as attributable to cotton thrips. In 1918–19 the pest reached such serious dimensions that the first entomologist in the Gezira, G. H. Corbett, was detailed in 1919 to start work upon it, and he was followed shortly afterwards by H. W. Bedford.

[1] ''Asal' is Arabic for honey. The name describes the slight stickiness of injured leaves.

Thrips cause a typical browning and silvering of infested leaves, which frequently wither and are prematurely shed. An infested leaf and boll are illustrated in Figs. 201 and 202. The appearance of the insect can be judged from Figs. 203 and 204, which show the fully grown larva and the adult female, both much magnified. In the field the insect passes unnoticed by the casual observer, for it is smaller than a pin's head, but the characteristic damage to the leaves is easily recognized.

FIG. 201. Cotton-leaf badly infested with thrips, showing silvery patches from which the insects have sucked the sap, and also the dark specks of excreta dropped by the thrips larvae (*photo by H. W. Bedford, W.T.R.L.*).

The adult thrips feed on sap extracted from the plant, and the eggs are laid within the leaf tissues, generally on the underside. They usually hatch in 8 to 12 days and the larvae, like the adults, are sap-feeders. Their excreta appear as dark specks on the characteristically silvered leaves. The fully grown larvae fall to the ground, become quiescent, and ultimately pupate below the soil surface. They are found especially in friable soil, as on the cotton ridges and banks of the irrigation channels, where the insect can move freely. They penetrate to any depth down to 4 in. according to soil-moisture and the need for protection from sun and heat. The length of time spent in the soil is variable, usually from 5 to 12 days but sometimes as long as 4 weeks, and then the adults emerge from the pupae and escape.

Each successive brood, having exhausted the sap of the lower leaves, moves to higher, newer leaves, until the pest may infest the entire plant. Under field conditions the insects first attack the smaller plants which have been sown later than the rest to fill in gaps in the stand, and from them

spread to the older plants. In severe cases stems, bracts, and bolls are also attacked, with great loss in yield. The damage caused by the pest varies greatly from place to place and from season to season. No estimate has been made of the financial loss over the Scheme as a whole, but it is recognized that where thrips infestation is severe yields are likely to be seriously reduced.

Thrips attack not only cotton but a wide range of other plants, ornamental as well as economic, including weeds. In the Gezira Scheme they are particularly partial to the weeds *Heliotropium europaeum* Linn. (Arabic: 'danab el 'agrab', scorpion's tail), *Leucas urticaefolia* Benth., and *Crotalaria* sp. At the onset of the rains each year, thrips are usually found first on these weeds. When towards the end of the rains the weeds dry off, the thrips migrate to the crops, especially to cotton.

FIG. 202. Cotton-boll badly infested with thrips, showing the silvering of the leafy bracts and boll-wall, a result of feeding by larvae.

Before irrigation came to the Gezira, thrips were recognized as a serious pest of riverain crops which, persisting throughout the year, favoured their spread, for thrips do not easily survive long periods in dry ground. The first two Gezira pump-schemes, Taiyiba and Barakat, were close to the river, and it seems likely that the thrips migrated from the river-banks to the weeds growing on the resting land within the irrigated areas and thence to the cotton. Bedford noted that weed-growth was especially vigorous on the resting land the year after an irrigated crop, and hence the natural hosts of thrips were increased in the immediate neighbourhood of cotton.

When once thrips settled on the cotton crop they tended to persist for the rest of the season; but under low temperatures their activity abated. Corbett and Bedford gave the following data comparing the incubation period of the eggs, and the length of the larval stage:

Month	*Mean minimum temperature (° F.)*	*Incubation period of eggs (days)*	*Length of larval stage (days)*
February .	57·8	13·0	6·0
March . .	63·3	8·7	4·8
April . .	65·1	6·5	3·9
May . .	73·9	. .	3·7

Both the incubation period of the egg and the length of the larval stage were shortened markedly by rise in temperature. Hence the greatest

activity takes place during the hot spells of September to November and March to May; and the yield of cotton is most seriously reduced in the former period when thrips are severe during the few weeks after the drying-off of the weeds on the resting land, at a time when the weather is hot and the young cotton plants are at a critical stage of growth. It was shown later by W. P. L. Cameron that two distinct species of thrips are involved; one is mainly responsible for the damage in the first hot spell and ceases to be a pest when the humidity falls in November, and

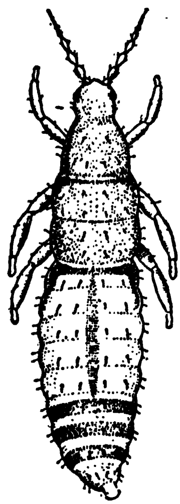


FIG. 203. Fully grown thrips larva (much magnified) (H. W. Bedford, W.T.R.L.).

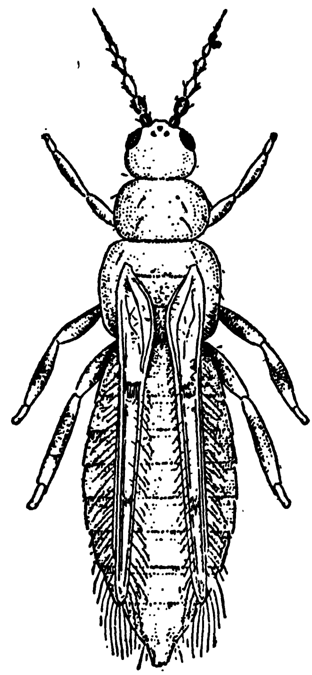


FIG. 204. Adult female thrips (much magnified) (H. W. Bedford, W.T.R.L.).

the other causes the less serious damage late in the season and in mild winters.

Bedford found that those cotton plants directly exposed to the north wind in the winter months were the most liable of all to thrips attack. Low humidity, though discouraging one species, is believed to favour the other, and the dry north wind lowers the humidity among cotton plants on any northern boundary. Bedford noted in observations at the Gezira Research Farm another associated effect, that whereas heavily watered plots were almost free of thrips, lightly watered plots were heavily infested, not only on the margins but right through the field.

Experiments on control, based on these observations, was therefore conducted on the commercial crop. In view of the role of weeds in acting as hosts, an obvious method was to eliminate the weeds on resting land, roads, and elsewhere. In the past, as at present, weeds were allowed to

ripen and dry off towards the end of the rains, but hand-hoeing of unripe weeds would ensure that the eggs and larvae of thrips were destroyed as the weeds dried in the sun. As an experimental measure the whole of the resting land of the Barakat pump-scheme was hoed in 1919–20, after the rains had ceased but before the thrips had migrated to the cotton. Moreover, because the northern sides of the fields suffered most, the cotton areas of the pump-scheme, totalling 2,056 feddans, were re-grouped so that pairs of cotton 'numbers' were grown side by side. Thus the cotton formed as large fields as could conveniently be supervised, and the proportion of marginal cotton and that in contact with resting land was greatly reduced.

These measures were not, however, a success. Although the hoeing of weeds on the resting land has recently been proved to increase the growth of cotton sown in the following year, as a means of controlling thrips it was ineffective. With the rotation employed at Barakat at that time, each cultivator had to hoe 20 feddans of weeds, an impossible task except in a year of light rainfall, especially since, under the regrouping, his resting land was often some distance from his cotton. Moreover, the unavoidable breaks in cropping caused by roads and water-channels were sufficient to allow thrips to enter.

The next possibility examined was to protect the cotton by belts and by trap-crops, on which the thrips might be concentrated and destroyed by spraying. As belts, pigeon-pea (*Cajanus cajan* (L.) Millsp.) was tried on an experimental scale in 1920–1, several rows being grown round the edge of the cotton plots, especially on the north side. This certainly reduced the more severe marginal damage, but did not solve the main problem. As a trap-crop, 'lubia' (*Dolichos lablab* Linn.) was grown in the furrows between the cotton, the intention being to spray the 'lubia' to kill the thrips expected to be concentrated on it. The thrips, however, failed to collect on the 'lubia', but at first attacked both crops and then, most surprisingly, left the 'lubia' for the cotton. The probable explanation of this became apparent later when Cameron showed that, of the two species concerned in the main attack on cotton, only one attacked *Dolichos*.

The straightforward methods, viz. picking infested leaves and spraying, were tried but were prohibitive on a large scale by their cost. Spraying experiments were made as early as 1919–20, and Corbett found that the most effective was a wash of nicotine sulphate in soap solution. Tests were made in mechanical spraying, a sprayer on wheels being drawn through the cotton ridges; but this method failed because, to quote Bedford, 'being originally intended for horse-draught, the slower rate at which the bulls walked reduced the pressure of the spray'.

It was therefore decided to concentrate investigations on the degree of control possible by heavy irrigation. During the peak of the thrips activity, October and November, the cotton is no longer very small and can therefore endure heavy waterings with little adverse effect. This method of control merited a large-scale trial, but unfortunately such trials were not possible with the limited water supplied by a pump-scheme. But when the opening of the Sennar Dam in 1925 ensured a plentiful supply, experiments on heavy irrigation could be extended. The new appointments

of research staff made at that period enabled Cameron to concentrate on the control of thrips, examining the problem from both the laboratory and the field points of view.

As mentioned above, he discovered that there were two species concerned with the main attack on cotton, and he found others too which damaged the terminal buds of young plants, especially those late-sown. The existence of the two distinct species in the main attack explained some of the contradictory results obtained earlier, for one (*Hercothrips fumipennis* Bagn. and Cam.) is the chief cause of the early damage, from September to November, but not afterwards, and the other (*H. sudanensis* Bagn. and Cam.), which breeds mainly on the weed *Leucas urticaefolia* Benth., is entirely responsible for the later damage, thriving under conditions of low humidity. With both species the extent of the damage appeared to depend on temperature, and abnormally mild winters led to increased damage.

Cameron found that, among thrips, females are usually about twice as numerous as males, and this preponderance of females with high fecundity readily explains the rapid multiplication of thrips in a suitable environment. In the off-season both species breed slowly on weeds in sheltered places and on permanent crops like lucerne (*Medicago sativa* Linn.). It is still not certain how far they are able to aestivate in the soil during the dry period, but some survival seems certain.

In the field wide-spaced cotton was found to be more prone to thrips damage than close-spaced, and late sowings more affected than earlier sowings. The effect of heavy irrigations, Cameron decided, was primarily one of sealing the pupae in the soil and preventing their emergence. Thus heavy irrigations, if given early enough, should check the multiplication of successive generations of insects. With this in mind he arranged large-scale experiments, in conjunction with the Sudan Plantations Syndicate Ltd., for the southern Gezira, where thrips tended to be worst.

The first experiments happened to be in an abnormally wet year, 1929–30, when the drying-off of weeds was delayed and the thrips were three weeks later than usual in migrating to the cotton. The damage to the cotton crop was correspondingly light, but none the less the benefit of heavy watering on the 500 feddans of experiment was evident.

The next year the rains ceased a fortnight earlier, and the anticipated severe thrips attack duly appeared in the first week of October. On the strength of the result of the previous experiments the Syndicate, in conjunction with the Sudan Irrigation Department, arranged that the irrigation interval was reduced from 15 or 16 days to 10 days. Water could not be supplied to the whole Gezira at that close interval, and the frequent waterings were therefore adopted in the most southerly blocks, especially on late-sown cotton. Markedly beneficial effects were observed, an counts of thrips emergence from the soil showed that the heavy irrigations had been completely effective in preventing further generations of thrips, and therefore heavier damage.

Finally, in 1932–3, on 360 feddans at Ghubshan watering at 12-day intervals from mid-October to mid-November caused the thrips attack to abate and the plants to make continued good growth. By contrast, where

irrigations were maintained at sixteen-day intervals, thrips persisted longer and the cotton suffered heavy leaf-shedding and growth was retarded.

With the recognition of the effectiveness of this measure when applied on a large scale, frequent irrigation has become an established practice. At first by co-operation between the parties the worst areas of thrips were recognized early each season and the water-rotation adjusted to ensure frequent irrigation there. Then, following upon the local success of the close interval and with improved irrigation facilities, the practice was extended until now the cotton crop of the entire Gezira is usually irrigated at 12-day intervals during the critical period, and this, as described under irrigation experiments, is also desirable husbandry. As a result of this change in irrigation practice it may be claimed that thrips no longer cause damage to the crop as they did formerly.

With American cottons grown in the rain areas this successful method of control is impossible. As an alternative in the Gedaref district Cameron tried the effect of earlier sowing. Whereas June sowings remained free of thrips and gave the greatest yields, later sowings suffered increasingly, until those of September failed completely. Evidently sowings should not be made after mid-July and, with this reservation, there appears no reason why thrips should seriously hamper the crop. That such early sowings are optimal for yield, apart from any question of thrips, has already been stressed in a preceding section.

Thrips have not been reported as causing damage to cotton in the Nuba Mountains, but they are frequently a serious pest in the Gash Delta.

Pink Bollworm (*Platyedra gossypiella* Saund.)

Pink bollworm is Egypt's major cotton pest, and in the years following its first appearance in 1911–12 it occasioned much loss of crop, destroying all the late-formed bolls. The seriousness of the loss led to many changes in the method of cotton cultivation, all tending towards earlier production of the crop, e.g. sowing earlier and at a closer spacing and the introduction of varieties which matured earlier than Sakel. Because of the Sudan's proximity to Egypt the spread of this pest was watched with anxiety, and control measures were started early, the Sudan profiting by experience in Egypt.

The first pink bollworm in the Sudan was recognized in 1914–15 in Tokar cotton. Shortly afterwards it was noticed in Berber, and then in places as far apart as Kassala, Singa, and Shambat, but not in the Gezira. H. H. King considered that it was probably imported into the Sudan from Egypt before 1913 in infested seed, for in 1912 about 280 tons of seed from the crop grown in Egypt in 1911 were sown at Tokar. The severity of this pest in the pump-schemes of the Northern Province was one of the causes which led to the recent suppression of cotton-growing there, and, but for the effective control measures now in force, it would probably take a heavy annual toll of the Tokar and Gash crops, and, to a less extent, of the Gezira crop too.

The various stages in the life of the pink bollworm are illustrated in Fig. 205, and the damage caused by it in Fig. 206. The bollworm lays its eggs on the leaves and bolls of cotton, and these hatch in about a week,

the newly hatched larva boring into a boll and feeding on the seed. After two to three weeks the larva is fully grown and may either bore its way out and pupate in debris on the ground, or may enter a resting stage, lying dormant for a period sometimes as long as 20 months, within a hollowed-out cotton seed or in two such seeds webbed together with silk.

Where the larva pupates straight away, the adult emerges after two or three weeks as a small brownish moth capable of laying eggs almost at once. Where the insect enters a resting stage it is enabled to survive the dry season and to pupate when conditions become favourable. In any season the early generations mostly pupate immediately, whereas the later ones produce proportionately more resting larvae.

In 1916–17 Tokar and the Berber districts both suffered appreciable loss of crop, and at once control measures, in the form of general legislation modelled upon that of Egypt, were begun. Resting larvae were known to survive among the cotton seed long enough to infest the next year's crop. To counter this the seed to be used for sowing was exposed in a thin layer to the hot sun of the Sudan summer for a period long enough to ensure that all larvae were destroyed. After experiment it was found that pink bollworm larvae cannot withstand for more than a few minutes a temperature of 122° F., whereas the germination of the seed is not impaired until much higher temperatures are reached. It was thought advisable to allow a considerable margin for the practical application of sunning on a large scale, and the standard now required is a temperature at or above 140° F. throughout the spread seed for a minimum period of two hours. By legislation all seed to be used for sowing must be adequately sunned. The supervision of this operation for the main cotton areas in the Sudan has been the responsibility of the Entomological Section for many years.

Not all the cotton seed produced by a crop is harvested, but infested seed falling to the ground is sunned naturally, while that remaining on the plants is destroyed effectively if the cotton stems, branches, and leaves are burned at the end of the season. Again legislation helped, and the regulations for collecting and burning cotton sticks were strictly enforced by close supervision, for, unless the burning were general to ensure a dead season, control would be ineffective.

The latest date for destroying the old crop and the earliest date for sowing the new one were fixed for each district, and as a further precaution the growing of okra, *Hibiscus esculentus* Linn. (Arabic: 'bamia'), an alternative host for pink bollworm, was in certain districts prohibited during the dead season. Legislation also forbade the import of cotton seed without permit, the removal of seed from one cotton district within the Sudan to another, and the storage of unsunned seed within the cotton-growing districts.

To study the effect on the pest of the enforcement by legislation of all known measures of control a laboratory was opened at Tokar in 1917 with, first R. E. Massey, and later H. W. Bedford, in charge. They checked the control measures very strictly and it was gratifying that, in a count of more than 10,000 green bolls, only 5 bollworms could be found, and that there was no loss of crop from the pest in 1917–18. In the follow-

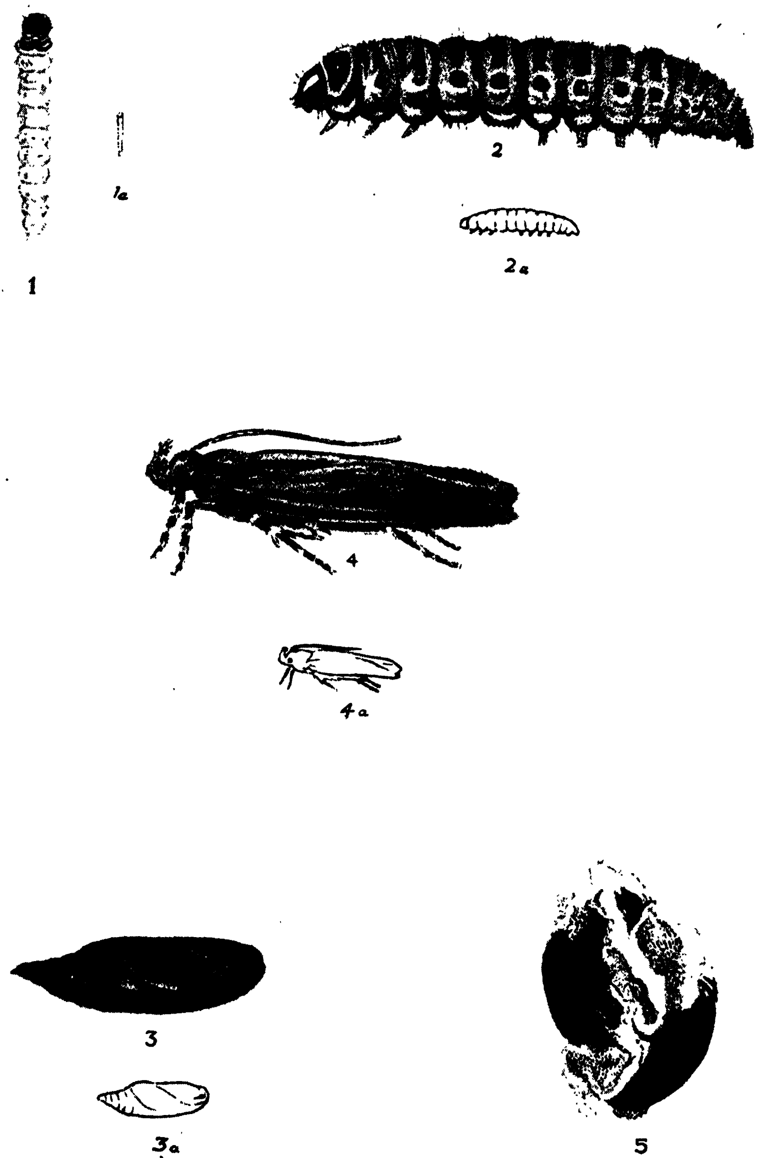


FIG. 205. Stages in the life-history of pink bollworm: 1 and 2 larva; 3 pupa; 4 moth. 1 (*a*) to 4 (*a*) are the natural size. 5 'Double seed' enclosing resting larva (*H. Bedford*).

FIG. 206. Cotton bolls damaged by pink bollworm: 6 and 7 green, immature bolls: 8–10 matured or dead bolls (*H. Bedford*).

ing season bollworm was again negligible, and the pest was considered to be under control.

Elsewhere the problem was less simply solved. At Tokar the annual flood brings a period of great activity, and this is followed by a spell when the district is almost deserted. Near the Nile there is no such well-defined natural dead season, for crops are grown near to permanent residences, and the river maintains at least a narrow belt of crops or weed-growth which enables insects to survive. Also, in the Northern Province, where the manufacture of native cotton cloth (damūr) is of long-standing importance, local cottons used to be grown expressly for this market, and King and Giffard decided that the survival of bollworm in this province occurred mainly in the seed-cotton and cotton seed stored in the houses. To enforce the law against the storage of unsunned seed was a difficult matter, for even if the cultivators were compelled to send all their crop to a factory for ginning, much inferior and infested material would be kept at home for local spinning.

The Government therefore offered to purchase all the seed resulting from a crop at a price attractive to the cultivators, even if financial loss was thereby incurred. This was tried in 1924 in the Berber district and also in the native-owned cotton areas of the Gezira. New seed for sowing was issued by the Government and it became an offence to sow old seed. In the first trial in the Gezira the American seed bought by the Government turned out to be that originally issued for sowing! Local seed, of indigenous or old-established varieties, however, was bought in large quantities, and this was heavily infested, at an average rate of four pink boll worm larvae per rotl of seed.

In the irrigated areas of the Gezira the risk of damage by pink bollworm has always been present. Although, through the centralized direction, control is more easily enforced, the crop is in the ground for 9 months each year, the Blue Nile flows along the entire length of the Scheme, and the whole area is dotted with permanent habitations, many dating from the period of rain-cotton and the damūr industry.

The Gezira Scheme first called for special attention in 1927 when the infestation was higher than before. In previous years the bollworms had been found to increase in number towards the end of the season, February to April, but even then had never reached high proportions. Counts made by H. B. Johnston in 1926–7 showed 13 per cent. of bolls damaged in the Wad Sulfab block by the end of March, and in view of this a general survey of the Gezira was made for the first time. Distribution of pink bollworm was found to be general and fairly even over the whole area, with a tendency to be heavier towards the north. In native-owned cotton cultivation along the river bank it was appreciably heavier than in the Syndicate area. Although the infestation in 1927 was not severe when compared with Egypt or the Northern Province, it was considered that greater efforts should be made to enforce the legislation. In the Gezira the seed for sowing and the cutting-out and burning of sticks were all centrally controlled, so the most likely means of survival of pink bollworm was, as in the Northern Province, in seed stored in native houses. To control this source of infestation the Government renewed its purchase of seed

in the northern Gezira, where the damūr industry was most active and the percentage of infested seed higher than farther south. The purchases, it was realized, would include seed from the seed-cotton brought home for spinning both from the native cultivation and, by theft, from the Gezira Scheme. In 1927, when considerable amounts were purchased, the seed was found to have an average infestation of about two live larvae per rotl. In the total clean-up, which embraced 140 villages, an estimated total of 43,000 larvae were destroyed.

The entomological staff noted that seed derived from native-owned cultivations contained a much larger number of larvae than that from the irrigated area, an isolated rotl of seed from one village having 30 living larvae. Following up this observation, it was found that pink bollworm infestation was higher where the irrigated area approached the west bank of the Blue Nile, presumably from a large carry-over in stored seed in the damūr industry and the presence of native-owned cotton along the river. As the area of the native-owned crop was small compared with that of the irrigation scheme, legislation was passed, in 1928, to forbid its cultivation within a prescribed radius.

It was also found that the cultivators within the irrigated area retained small quantities of Sakel cotton in their houses, and samples of this showed an average infestation of 1·4 living larvae per rotl. Propaganda was made against this practice, and subsequent inspection indicated a considerable, if only transient, improvement.

Thus the standard methods of control appeared to apply in the Gezira as elsewhere; but one result was puzzling. Although legislation to prevent cotton-growing on the banks of the river had been strictly enforced, the same relatively high infestation remained in the areas of the irrigation scheme nearest the river. An inspection of the west bank by A. H. Wood in July 1936 revealed large numbers of the larvae in *Hibiscus esculentus* Linn. ('bamia') grown out of season despite regulations. Up to 30 per cent. of the old fruits were infested and up to 15 per cent. of the young fruits. This danger of carry-over of pink bollworm from out-of-season 'bamia' was clearly demonstrated when it was sown experimentally on the Gezira Research Farm in February, April, and July, 1940. All fruits half-grown or larger were collected at weekly intervals and examined. The average percentage of fruits damaged by pink bollworm between mid-May and the end of August was 10·1 per cent. with a maximum in August of 24·5 per cent., when an average of 41 larvae were found per 100 fruits.

The presence of out-of-season 'bamia' along the river banks and the demonstration of a high percentage of infestation of 'bamia' fruits by pink bollworm in an experiment do not alone prove conclusively that out-of-season 'bamia' was responsible for the higher infestation of the Gezira cotton crop near the river. Yet the evidence was considered sufficient to justify the passing of additional legislation to prohibit the cultivation of okra in and around the Gezira Scheme between 1 June and 15 September. This covered not only the dead season for cotton but a month after cotton-sowing. The suppression of okra during the rainy season is inconvenient to the cultivator, for variety in food is very limited, but

it will be shown in a later section that its suppression may be desirable also for the control of leaf curl disease.

Much effort has been expended by the entomology staff, year by year since 1927, to determine accurately the damage to the Gezira crop by bollworms, and large numbers of green bolls have been collected for examination in the laboratory, both at the Gezira Research Farm and on the commercial crop. Comparable data from the Gezira Research Farm on bollworm infestation for five successive seasons are shown in Fig. 207. Fig. 207 (*a*) shows the percentage of bolls damaged by pink bollworm for successive half-months during the season. In some years towards the end of the season more than half the bolls on the crop were damaged. Deductions drawn from these percentages alone are, however, misleading, for the total number of bolls present in each half-month must be taken into account. Early in the season when bolls are plentiful the percentage is low, and it increases to high values only when the total bolls are few. This is emphasized diagrammatically in Fig. 207 (*b*) which shows the numbers of total and damaged bolls summed from consecutive half-monthly counts. Although by this method individual bolls are counted more than once so that the cumulative curves do not show the true number of bolls, the curves of total and damaged bolls are comparable. In no year were more than 10 per cent. of the total bolls produced by the crop damaged by the pest, and, over the five years, the average was only seven per cent. Since a damaged boll usually still produces some seed-cotton, it is estimated that for this experiment the loss in yield from pink bollworm did not exceed 2 to 3 per cent. each year.

In other laboratory work Johnston, studying the method of survival of the resting larvae, showed that they are killed primarily by high temperatures. Larvae in fallen bolls are killed by the sun, and their survival in the dead season is only possible in such shady conditions as inside buildings. T. W. Kirkpatrick, extending Johnston's work, recorded by means of a light-trap the date at which bollworm moths emerged from a large quantity of infested seed which had been stored (v. Fig. 208 which gives averages from observations made in 1929 and later years). Contrary to expectation it was found that, at whatever date between February and May the bolls were picked, the peak of moth-emergence occurred at approximately the same calendar date, the rate of emergence apparently being determined by external conditions. This meant that the February larvae rested 3 months longer than the May ones. Few moths emerged before July, but the emergence then increased rapidly, reaching a peak in early August, the time of the highest humidity. Emergence fell off rapidly afterwards and very few appeared in September and October. This experiment, when repeated for several years, showed the date of maximum emergence to vary only slightly from year to year. It has also been undertaken in the Northern and Khartoum Provinces and in the Nuba Mountains and Equatoria Province.

Further experiments in the Gezira, designed by Wood and carried out by D. J. Lewis and W. Ruttledge in 1936, showed that the maximum emergence from resting larvae occurred at a temperature of 85° F. with a humidity of 80 per cent. Other work indicated that annual differences

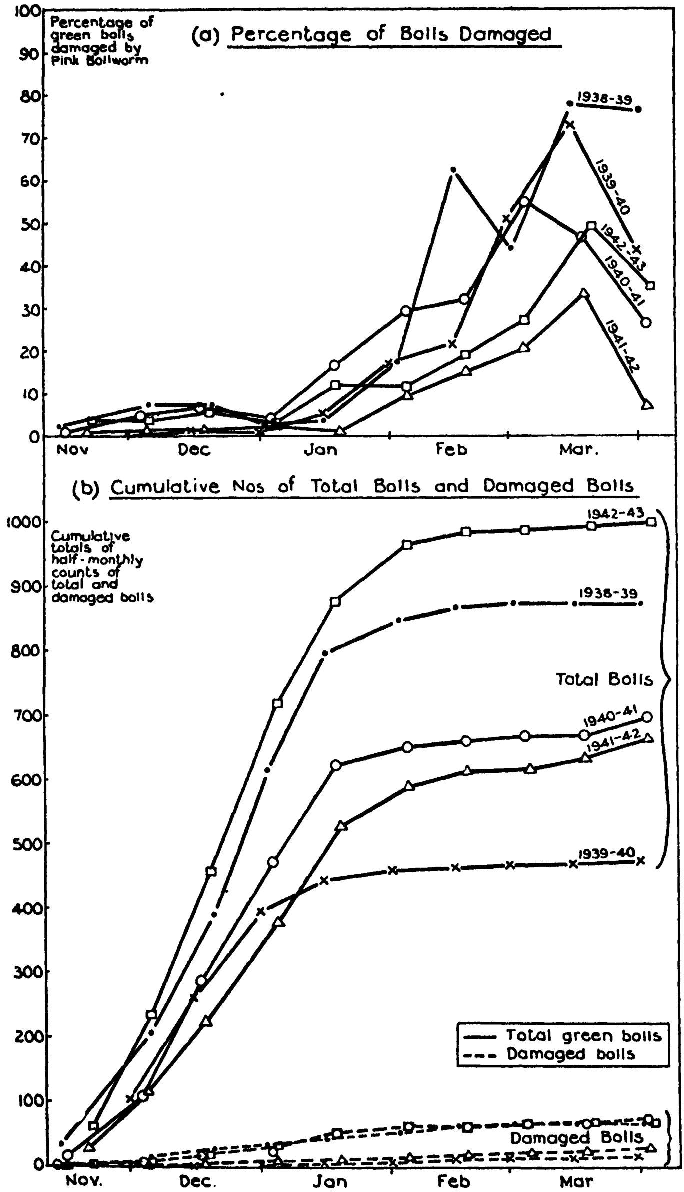


FIG. 207. Counts of bolls damaged by pink bollworm, from five years' data at the Gezira Research Farm: (*a*) damaged bolls expressed as percentage of the total number of bolls present (only bolls of diameter exceeding 18 mm. counted); (*b*) cumulative curves giving diagrammatically a comparison between the numbers of total bolls and damaged bolls throughout the season (*graphs by Ent. Section, G.R.F.*).

in the amount of damage to the crop by pink bollworm were linked with annual differences in the number of bollworms present on the crop at the start of boll-production. This result stressed the paramount importance of an effective dead season. When the cotton is sown in August, as at present, there are no bolls until late October, which means that, since the peak of emergence of resting larvae is in August, most of the moths die without reproduction. It is clearly very important that no alternative host, such as 'bamia', should be growing and flowering before late October,

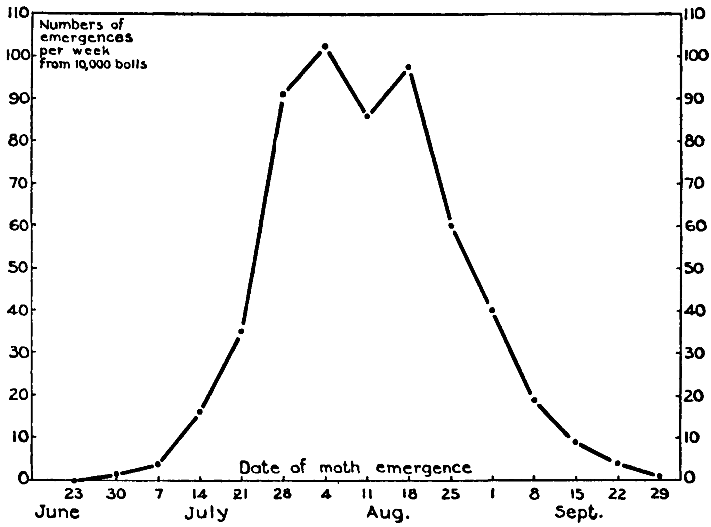


FIG. 208. Date of emergence from resting larvae of moths of pink bollworm. The data are the average of nine years' results over the period 1929 to 1939, 10,000 bolls being collected each season (Ent. Section G.R.F.).

or it will serve as a nursery to sustain the bollworms until the cotton is ready. It also follows that earlier sowing of cotton tends to increase the pest.

So far in the history of the Gezira Scheme, pink bollworm has never caused heavy loss in the yield of cotton over a large area, and the annual loss in the whole scheme from this pest is at present small. What the position would have been in the absence of control measures it is impossible to say. It seemed wiser to keep down the loss of crop from pink bollworm damage by preventive measures rather than risk an unrestricted, and possibly rapid, increase of the pest, which would then have called for more extensive and costlier measures than those now in operation. Nevertheless the local suppression of the 'damūr' industry and the prohibition of 'bamia' cultivation at certain periods of the year are irksome restrictions inflicted upon a section of the population which itself receives little direct benefit from the reduction in pink bollworm and which needs the addition to its diet of such nutritious foods as okra.

JASSIDS OR COTTON LEAF HOPPERS (*Empoasca libyca* de Berg)

It is only within the last 10 years that jassids have been recognized as a serious pest of cotton in the Sudan. Apparently they are increasing in number in the Gezira Scheme, especially in the northern blocks, and in the absence of any known method of control workable on a commercial scale, this menacing pest calls for immediate attention. At the present time it holds an important place in the research programme.

Several species of jassids affect cotton in different parts of Africa. Unlike pink bollworm, they are not a cotton pest in Egypt, but they abound in West and South Africa, cotton cultivation only surviving in the latter through the production by F. R. Parnell of resistant varieties.

No investigations on jassids were made in the Sudan until 1929, when, because of a suggestion that they might be associated with the spread of leaf curl disease, A. P. G. Michelmore studied their life-history. He found that an egg and nymph stage of short duration is followed by a long adult life in which the female lays her eggs in small numbers over a long period. The particular species which fed on cotton in the Gezira (later identified by Prof. Paoli as *Empoasca libyca* de Berg) fed also on a wide range of host plants, not only on those related to cotton but on such plants as *Ricinus communis* Linn. (castor oil), a perennial, and *Solanum dubium* Fresen., a common weed. Obviously a method of control which depended upon an effective dead season could have little success with jassids.

Michelmore described how, when jassid nymphs were allowed to feed on caged cotton plants in numbers sufficient to make a large population on a single leaf, the leaf dried up from the edges. Yet he added: 'In the Gezira leaf hoppers appear not to hurt the cotton crop, even when they are present in much greater numbers than those which are stated by Parnell to cause serious damage in South Africa. Up to the present no evidence at all has been found to suggest that cotton leaf hopper is of the slightest importance in this country, in spite of its abundance.' It is impossible, in the absence of precise records, to state categorically whether on any large commercial area a pest is more prevalent than formerly, but it seems probable that there has been since 1939 a very large increase in the number of jassids over much of the Gezira, for nowadays 'hopper-burn', as the colouring and drying of the cotton leaf-margins are termed, is noticeable even to the casual observer.

Michelmore discontinued his investigations when it was found that jassids were not involved in the spread of leaf curl, and no more observations were recorded until 1933, when Cowland stated that jassids were very numerous in the northern blocks of the irrigated area. Marginal yellowing and dryness of leaves were conspicuous in the Gezira by that time. For example, they were considerable on the outstation experiments conducted in the northern Gezira in 1933–4, F. Crowther ascribing the symptoms to the effect of water-strain, caused by the very hot weather and low humidity prevalent in late October in that region. Later, however, Cowland obtained similar marginal damage on the leaves of cotton plants growing in cages in a more favourable climate, when, and only when,

jassids were admitted. This can be taken as proof of the existence of hopper-burn in the northern Gezira by 1933–4. Since then it has become more severe and more widespread, much of the cotton crop of the central Gezira also now being attacked annually.

Cowland, comparing the symptoms of hopper-burn on different cotton varieties, found that the Egyptian strains comprising the Gezira crop exhibited mainly yellowing of the leaves, and not the deep red blotches which characterize jassid damage on American cottons. The hoppers, when numerous, on young leaves caused wilting of the margins at midday,

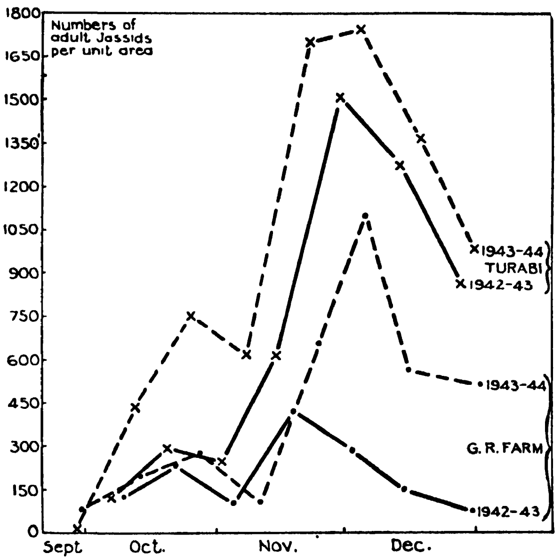


FIG. 209. Numbers of adult jassids on cotton, determined by a standardized method of sweeping, at fortnightly intervals. The counts were made on the Gezira observation plots at Turabi (northern area) and the Gezira Research Farm (central area) (J. W. Cowland (original)).

and on older leaves a yellow marginal band, sometimes narrow, sometimes spreading well into the centre of the leaf, resembling sun-scorch. These marginal areas ultimately dried and disintegrated, leaving a tattered periphery to a leaf which was otherwise still green and turgid.

Counts of adult jassids, made fortnightly by Cowland by a standardized method of sweeping cotton plants with a net, are shown in Fig. 209 from experiments in the northern and central Gezira. Numbers were always low until the end of September, about 6 weeks after sowing, after which they increased gradually in October and rapidly in November, to a peak at about the end of the month. The numbers fell away sharply from early December. The northern plot had two to four times as many as the central, Gezira Research Farm, plot, which agreed with observations noted in earlier years of the distribution both of the jassids themselves and of hopper-burn.

Following the example of workers in the U.S.A. in the control of another species of jassid, in 1941–2 Ruttledge tried to control the pest by spraying

with Bordeaux mixture, a copper sulphate and lime spray originally introduced against mildew on grapes in the south of France. That a fungicide should be effective against an insect is surprising, and the degree of its success in these Gezira experiments surpassed all expectations. After three sprayings made during October and November, the sprayed plots in December stood out dark-green among those yellowed by hopper-burn, giving a chequer-board effect. The final yields of cotton were:

	Yield (kantars per feddan)
Unsprayed	5·92
Sprayed	6·63
Increase by spraying . . .	+0·71

The increase from spraying was 11 per cent. which may be ascribed directly to reduction in amount of jassid damage, since copper and calcium sprays in earlier experiments on mineral deficiencies had been without noticeable effect on yield. The experiment was repeated the following year, both at the Gezira Research Farm and in the northern Gezira, the yields being:

	Yield (kantars per feddan)	
	Central (*G.R. Farm*)	*North* (*Turabi*)
Unsprayed	7·08	4·76
Sprayed	7·91	5·93
Increase by spraying . .	+0·83	+1·17

The increases were 12 and 25 per cent. for the central and northern areas respectively.

These figures indicate the enormous financial loss incurred at present from jassid damage, for, since there is no reason to believe that numbers at Turabi were abnormally high for the district, the inference is that about a quarter of the entire crop from the northern blocks may be lost annually from jassids. With the present distribution of varieties this loss is greatest where the most valuable variety, Sakel, is grown exclusively.

Present investigations on means of reducing this loss of crop are proceeding in two main directions, viz. on spraying and on breeding resistant varieties. The spraying experiments should show what amount of Bordeaux mixture per feddan will suffice and what is the best time of application; at present the cost of chemicals is prohibitive and their application on a large scale exceedingly difficult unless dusting by aeroplane can be introduced. In the plant-breeding work, R. L. Knight and J. W. Cowland are investigating the jassid-resistance of certain varieties, in an endeavour to add this resistance, by methods developed successfully by Knight against blackarm disease, to the improved strains of cotton now becoming available for both the irrigated and the rain areas of the Sudan.

COTTON STAINER-BUG (*Dysdercus* spp.)

Unlike the other insects so far described, stainers, or stainer-bugs, in the Sudan are not a pest of irrigated cotton. They are found on rain-grown American cotton, and are prevalent in Equatoria Province, and become a serious pest in the Nuba Mountains.

Their distribution as a pest is partly determined by the amount of annual rainfall, for no species of stainer is plentiful where the normal rainfall is below 20 in. This in the Sudan confines the pest almost entirely to south of the 14th parallel of latitude, that is, south of all irrigation schemes. Strangely enough, the species most important in Equatoria Province has been found also in small numbers on cotton as far north as Zeidab (lat. 17° 26′ N.) and Tokar (lat. 18° 26′ N.).

Stainers first attracted attention as a pest in the Sudan when in 1924 the Nuba Mountains district was opened up for the cultivation of American cotton. They appeared at once and damaged the crop so badly that the success of the project was threatened. As a result, observations were started by Cowland and Ruttledge in 1926 and continued by F. G. S. Whitfield in 1928.

The stainers of the Nuba Mountains, though they may suck sap and nectar from various plants, can only obtain sufficient nourishment for growth and reproduction from the seeds of a limited number of species. They may feed on ripe seeds, or, since the species possesses a very long proboscis adapted for piercing and sucking, on unripe seeds within the green fruit. All but the youngest nymphs are capable of feeding on the seeds within green cotton-bolls, and although the damage does not become apparent until the boll ripens and opens, it is feeding at this stage which causes the characteristic damage which gives the pest its name. The stain is caused by the development within the boll of specific bacteria and fungi, particularly fungi of the genus *Nematospora*, introduced by the proboscis of the insect. Not only is the lint stained a bright yellow, but its fibres are weakened, and the seeds cease developing. A boll attacked at an early stage may contain little beyond proliferated and decayed tissues. After the boll opens no further fungal damage can take place, but another, quite superficial staining of the lint, sometimes mistaken for the real one, is caused by the fluid excreta of the bugs.

Four species of the insect are recorded in the Sudan, but most damage is caused by *D. fasciatus* Sign. in the Nuba Mountains and *D. superstitiosus* F. in Equatoria Province. Since much more cotton is grown in the Nuba Mountains than in Equatoria Province, it is on *D. fasciatus* that most investigations have been made. The life-cycle of this species revolves around the baobab tree (*Adansonia digitata* Linn., Arabic: 'tebeldi', v. Fig. 210) and, except on cotton, it is rarely found elsewhere. This association is not only fascinating as natural history but is exceptionally good fortune from the point of view of pest control.

The stainers are not new arrivals in the Nuba Mountains and they have come to the fore recently only because of the economic importance of cotton as compared with 'tebeldi'. Though their range of hosts is restricted to certain related plant families, it happens that the cotton plant belongs to one of them. The insect can fly a distance of several miles, and, since

it is subject to a seasonal dispersal at a time when the cotton is bolling, it finds in the crop a rich supply of food.

The eggs are laid just below the soil surface and hatch usually in 7 days. In about a month the insects become adult and start breeding, the females laying large batches of eggs at intervals of 7 to 10 days for several months. There is no resting period and breeding goes on throughout the year, at

FIG. 210. 'Tebeldi' (*Adansonia digitata* Linn.), showing fruits (*photo by W. Ruttledge*).

rates differing widely with changes in temperature and humidity. During the rains the numbers increase rapidly and large colonies of the insect, which is gregarious, gather in cracks and hollows in the bark of the *Adansonia*, giving a red colour to considerable areas of their trunks. They cluster, merely for shelter, on any plants growing either under baobab trees or in cotton fields, and very occasionally are found feeding and breeding on plants of *Hibiscus* spp.

The 'tebeldi' trees flower during April and May before the rains, producing large oval fruits (v. Fig. 210), each of which consists of an outer shell enclosing numerous seeds. Many fruits fall to the ground in September, and, either from the fall or from termite attack, split open, exposing an abundance of seed. It is at this period that the breeding of the stainers

is most rapid; and then follows the annual dispersal during which the cotton becomes infested (v. Fig. 211).

Breeding is noticeably retarded by the hot dry weather which comes towards the end of the cotton season. When the cotton is cut out and burnt, towards the end of March, the stainers resort to the 'tebeldi' and, although numbers are greatly reduced by the rigours of the dry season, enough survive there to ensure rapid increase when the rains come.

Control measures are likely to be most effective if they attack the insects when on the trees. These trees, few in number, stand out as landmarks in the countryside, for many of them grow in the vicinity of hills or high

FIG. 211. Stainer-bug (*Dysdercus fasciatus* Sign.) on cotton (*photo by W. Ruttledge*).

ground. The procedure adopted, therefore, is to locate all baobab trees within several miles of cotton and destroy all the stainers on them.

The first method of destruction attempted was by a blow-lamp flame, for the stainers cluster low down on the trunk, seldom above 10 ft. from the ground. This method proved too slow, and was superseded by spraying with neat paraffin which was afterwards ignited; this proved very efficacious. In the early trials, sprayings were made periodically throughout the season, but the most effective scheme has been to spray the stainers on the trees twice in the year, once in June–July at the onset of the rains, while the population is at its minimum after the dry season, and again in September, before the large-scale dispersal which results in the infestation of the cotton.

For complete control of the pest the destruction of all the 'tebeldi' seeds would be necessary, but cutting down the trees was thought undesirable, since, not only are they beautiful but their bark is a valuable source of rope to the local inhabitants.[1] Whitfield found that pollarding the trees

[1] In places these trees, while still living, are hollowed out and used as water tanks.—*Editor.*

stopped fruiting for 2 years at least, and subsequent new growth could easily be removed at intervals. This method was tried, but even pollarding destroyed much of the beauty of the trees, and for some years has not been practised except in one area, Tegali, where the trees are especially numerous near the cotton cultivations. Here, most of the trees are pollarded and repollarded, and the remainder, acting as traps, are sprayed with paraffin.

In general, widespread pollarding is not deemed necessary, since spraying, if combined with early removal of cotton sticks and destruction of all cotton-seed at ginneries and elsewhere, has proved a sufficiently effective method of control. Moreover, the cultivators are constantly urged to plant their cotton at a distance of several miles from baobab trees, a practice also desirable agriculturally, since most of the trees grow on the poor, light soil of high ground. These measures must be continued if the stainer population is to be kept down, but where they are enforced damage to the crop is very slight.

In Equatoria Province the problem is less simple, for the absence of a very pronounced dry season not only encourages the survival of the insects but also renders control more difficult. Moreover, the species is different. *D. fasciatus* Sign., which thrives in the Nuba Mountains where rainfall is from 20 to 30 in., is entirely absent from Equatoria Province, and so also, at least in the cotton districts, is the 'tebeldi'. It is interesting, however, to note that *D. fasciatus* Sign. reappears south of the Equator, again in association with *Adansonia*. The other species, especially *D. superstitiosus* F., flourish where rainfall is up to 48 in. Presumably they usually find the Nuba Mountains too dry, but in some seasons *D. superstitiosus* F. has been found there in considerable numbers on both 'tebeldi' trees and cotton. In Equatoria Province this species feeds on the seeds and fruits of a number of wild host plants including the tree *Sterculia cinerea* A. Rich. This tree occurs throughout the Nuba Mountains, but only once in nature has *D. superstitiosus* F. been observed feeding on it there, though it can be reared on its seed in the laboratory. It can, in certain circumstances, complete its development on the unripe heads of dukhn (*Pennisetum typhoideum* (Burm.) Stapf and Hubbard) and dura.

The other two species of stainer which occur in Equatoria Province have similar but not identical ranges of host plants, hence the measures used in the Nuba Mountains for the control of stainers are inapplicable. As an alternative, R. C. Maxwell-Darling found that in Equatoria Province two men in one day can destroy, by hand-picking, all the insects on a feddan of heavily infested cotton, and that this measure, repeated at intervals, is sufficient to keep under control the damage from the pest, so long as it remains at its present intensity.

DURA-BUG OR ''ANDAT' (*Agonoscelis versicolor* F.)

This pest of dura, known in the Sudan as ''andat', is a pentatomid bug which in some years destroys completely the heads on large areas of the crop both within the Gezira Scheme, particularly the southern blocks, and in the rain areas east of the Blue Nile. The dura-growing areas of the Gedaref district are also liable to attack, but very little damage from it

has been observed in the large areas south of latitude 13° N. and in the White Nile districts and Kordofan. Although the insect occurs widely throughout Africa it is only in the Sudan, and within the above-mentioned limits, that it constitutes an important pest.

Unlike the cotton stainer-bug, it has been recognized as a pest for many years and the date of its first attack is unknown. H. H. King, who first described it in the Sudan, mentions the serious damage it caused, not only in 1906, but 25 years previously. More recently, damage was

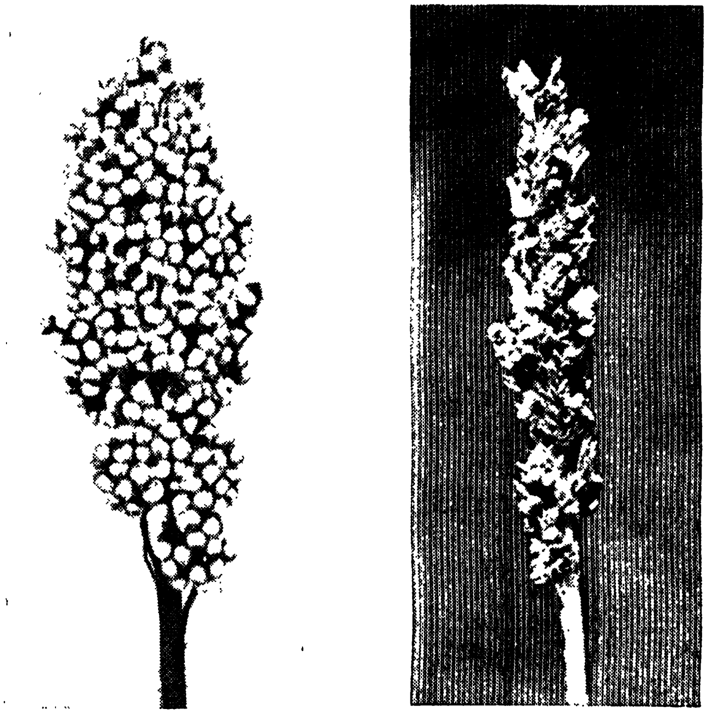


FIG. 212. Normal dura head and head damaged by ''andat' (*Agonoscelis versicolor* F.) (*photo by F. G. S. Whitfield, Bull. Ent. Res.*).

particularly severe in 1927, and less so in 1932 and 1942. Whitfield who, with Cameron, has done most of the work on this pest in the Sudan, noted that years of heavy rainfall with humid winters favoured the multiplication of the insects and their survival until the following rains.

The kind of damage caused by ''andat' is illustrated in Fig. 212. The adult insect feeds on the developing heads, taking a sip at each grain while it is at the soft, milky stage. After the piercing the grain becomes atrophied. Since in a year of heavy damage there can be twenty or more insects feeding on a single head, the entire head may become sterile, and, since every head may be attacked, the resulting crop may yield only straw.

Whitfield found that the insects take from 3 to 4 weeks to develop from eggs to adults, and, unlike the stainers, they breed only in the rainy season. During early August they leave the trees and bushes which have

sheltered them during the dry season and migrate to herbaceous plants which are usually growing rapidly after recent rain. The date of the migration appears fixed, and if the rains are late many bugs perish through lack of suitable weeds. This happened in the Gezira in 1933–4. Incidentally it will be interesting to note whether the early destruction, by hoeing, of weeds on the resting land, described earlier (p. 482) has any effect on ''andat' and other pests.

The commonest hosts are lucerne (*Medicago sativa* Linn.) and the weeds *Leucas urticaefolia* Benth., *Heliotropium europaeum* Linn. (both of which may be the hosts of thrips also during the same period), and *Ocimum basilicum* Linn. The bugs breed rapidly and can produce very large numbers of eggs. The nymphs hatched from these become adult during September, and, with the drying of the weeds, migrate to the dura, as the thrips migrate to the cotton. The dura crop, which is sown about the time the weeds germinate and which flowers about 6 weeks after sowing, is at the stage of developing grain when this migration takes place. Unlike the stainers, ''andat' rear only one brood each year, and there is only one migration, but the dura is just at the right stage to meet the insects' needs. Earlier sowing, to bring the dura to maturity before the migration, is impossible through lack of rain or irrigation water.

When the dura ripens about November the insects seek shelter and, again unlike the stainers, go into a resting stage of about 9 months' duration each year! Normally in this resting period they consume no food and move but little, remaining clustered in masses on tree branches and twigs, as shown in Fig. 213. In the Gezira after a season when the dura crop has suffered severely from their incursion, they are to be found throughout the winter months in their millions, massed together because of the scarcity of shade, so that the trees when viewed from a distance look yellow-brown from the colour of the insects. They show a preference for certain types of trees, including *Balanites aegyptiaca* Del., *Ziziphus spina-christi* Lam., and *Phoenix dactylifera* Linn., the date-palm, where this last grows along canal banks.

Whitfield found that where the shelter is sufficiently dense the insects remain motionless; they move at any time during the 9 months if it becomes necessary to find shelter from the sun. In cold weather they become so insensitive that they can be brushed off the trees in clusters 'which fall to the ground like so much wax and do not even disintegrate on the impact'. When the new rainy season comes round the bugs grow active, leaving their resting place temporarily but returning to it until early August, when they all disperse to feed and breed on the weeds, none remaining on the trees.

Whitfield and Cameron noted that the pest was worst in wet years and in the year following a wet year, presumably because heavy rains cause thick weed-growth and, at least in the rain areas, good dura crops. Changes in number of this pest may also be associated with attacks by parasites, for, in 1928, the year following a particularly heavy outbreak, it was noted that at least 70 per cent. of the eggs observed at the Gezira Research Farm contained parasites and would therefore fail to hatch.

Control measures were first started after the severe damage which occurred in 1927, when the monetary loss over a relatively small part of

the Blue Nile Province was at least £E50,000. Spraying the clustered bugs with neat paraffin was found very effective and was used exclusively in the first campaign. In more recent years methods of control, cheaper but somewhat less effective, have been adopted, e.g. dislodging the "andat' from the trees and burying them.

FIG. 213. "Andat' (*Agonoscelis versicolor* F.) clustered during resting period (*photo by F. G. S. Whitfield, Bull. Ent. Res.*).

Whitfield and Cameron concentrated on the trees within the infested areas of the irrigation scheme and on the district of rain cultivation east of Wad Medani, shown on the sketch-map in Fig. 214, prepared by Whitfield. The map shows the resting places in their relation to the dura cultivation of the neighbourhood and illustrates the importance of humidity in the distribution of the insects. The village of Wad Bakr, which is situated about 13 miles east of the junction of the rivers Rahad and Blue Nile, downstream of Wad Medani, stands on fairly high ground surrounded

by a large area of dura. West of the village is a shallow valley, shaded in the map, which becomes a lake during the rains and maintains a higher humidity during the dry season than the surrounding country. Here the trees are a favourite resting place for bugs which attack the dura all around. To illustrate the amount of labour required in control, Whitfield and Cameron stated that in May 1928 these trees were cleared of bugs in 10 days, using 30 men daily. A total of 482 gallons of paraffin was required to cleanse 1,187 infested trees. Ladders were necessary, for the dura-bug, unlike the stainer, does not confine itself to the lower parts of the trunk. Similar measures were taken on other infested areas situated on the banks of the Rahad (v. Fig. 214).

The scale of the 1928 campaign can be judged from the following table, which gives also an estimate of the number of bugs destroyed:

Site of operation	*Gallons of paraffin consumed*	*Estimate of nos. of ''andat' destroyed*
Rain cultivation, east of Wad Medani	3,720	82 millions
Irrigated area	3,040	48 ,,
Total	6,760	130 ,,

The numbers destroyed were estimated by weighing those killed by 4 gallons of spray, and the figure was checked at intervals. The campaign destroyed a volume of bugs of more than 5,000 petrol tins and the total cost, including paraffin and labour, was about £E750.

The following year ''andat' were few, and the damage to the crop negligible. As there was no similar area left untreated for comparison, the disappearance of the pest cannot be ascribed with certainty to the control measures, but since the number of bugs destroyed represented a large proportion of the total population, from a knowledge of the insect's life-history there seems no reason to question the success of the campaign. 1927 was followed by a number of years when the damage to crops was negligible.

In 1931 these bugs were found to be increasing again, especially in the irrigated area, and spraying was undertaken in the southern Gezira early in 1932. Although the following rains were heavy, favouring the pest, little damage occurred. In subsequent years, if the pentatomids were seen to be obviously on the increase, control measures were arranged in the summer months, and, although in some years damage has been severe locally, destruction of the bugs has always been followed by little damage in the succeeding season. That there was any damage at all shows that the measures taken were insufficient.

Inadequate control can arise from two causes, the adoption, in the interests of economy, of cheaper but less effective methods, and insufficient supervision. In an endeavour to cut down the cost, various sprays, including nicotine sulphate, have been tried successfully, but the method now in use is to jerk the bugs from the trees and shrubs in the early morning when they are torpid, and sweep them into prepared trenches which are

then filled in. This procedure is simple yet effective if organized properly and carried out thoroughly. It is so well suited to remote districts, since it requires neither imported materials nor expert direction, that it is surprising that the villagers did not discover the method for themselves

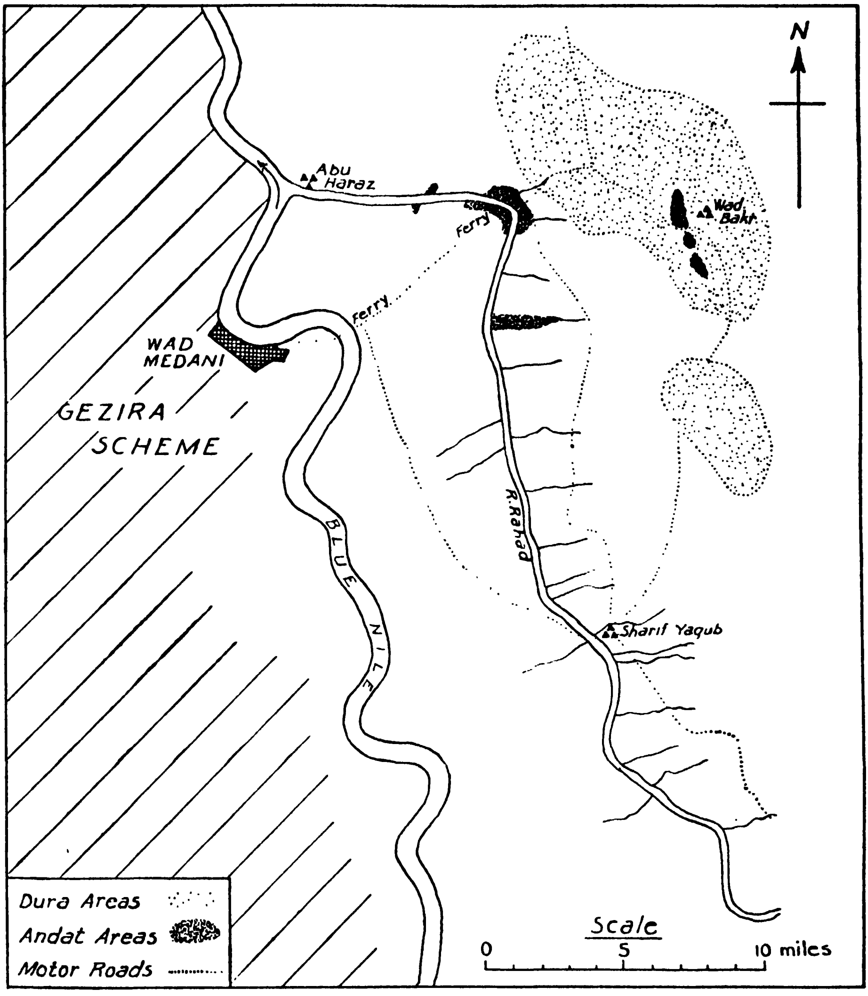


FIG. 214. Sketch-map showing the distribution of ''andat' (*Agonoscelis versicolor* F.) in 1928 in relation to the dura areas east of Wad Medani (F. G. S. Whitfield and W. L. P. Cameron in *T.R.L.*).

long ago. Now that its efficacy has been demonstrated, and benefit, in the form of additional dura, seen to result from its use, it is hoped that the amount of supervision needed can be gradually reduced.

V. MAJOR CROP DISEASES

Two diseases of cotton, blackarm and leaf curl, have become almost household words in the Sudan because of their association with failure of the crop; for, at a time of world economic depression and low prices,

failure of the cotton crop in the Gezira imperilled the prosperity of the entire country. Extracts from Government reports[1] illustrate the apprehension with which these two diseases were viewed; of 1930–1, 'In the Gezira . . . a poor stand resulted from severe attacks of black arm . . . the resulting plants achieved a poor growth and were heavily infested by leaf curl disease, crop prospects became gradually worse, the final yield of 1·34 kantars per feddan being the lowest yet experienced', and again of 1932–3, 'Serious damage was caused by black arm and leaf curl and the yield was expected to be considerably below the previous season'. Hence control of these two diseases appeared essential for the continued prosperity of the country, for it was on them that the blame was laid for a loss of crop amounting in value in a single season to more than a million pounds sterling.

Blackarm occurs not only in the Gezira but in the irrigated cotton of Tokar and the Gash and it is widespread in the rain-grown cotton of the Sudan. Leaf curl càn cause damage wherever the Sakel variety is grown. A third disease of cotton in the Gezira, wilt, is also described in this section, and this by affecting the roots, and thus, unlike blackarm and leaf curl, operating out of sight, may be responsible for a loss of crop greater than is generally recognized. These three cotton diseases, because of their economic importance, have dwarfed all others in the Sudan of whatever the crop, and investigations in plant pathology have centred around them.

BLACKARM (*Xanthomonas malvacearum* (E.F.S.) Dowson)

T. Trought has pointed out that, by the symptoms described, the cotton crop at Shambat evidently suffered a severe attack of blackarm as early as 1909. The earliest reports on irrigated cotton in the Gezira refer to a disease which, by description and relation to weather conditions, appears almost certainly to have been blackarm. Thus a report of the Sudan Plantations Syndicate Ltd. for 1912–13 on Taiyiba stated: ''Asal' damaged the crop severely during October'; and 'Stems in many cases became blackened and broke off about two-thirds from the ground'. The word ''asal', Arabic for 'honey', as used at that time included a variety of leaf disturbances, but later reports differentiated between dry ''asal' caused by thrips and wet ''asal' caused by blackarm. In the light of subsequent experimental work some early observations are interesting. The Taiyiba report for 1914–15 stated: 'The cotton on the new land has withstood the ''asal' much better than that on the old. . . . The earlier cotton has been much more damaged than cotton planted say fifteen days later'; and the Barakat report for 1916–17, a year when October rainfall was exceptionally heavy: 'Early in November the leaves and bolls showed signs of drying up, and in the old land there is little left of the plant except the main stem. Bolls, flowers and leaves have all dropped off.'

It may therefore be assumed that blackarm has been present in the Gezira from the beginning of the irrigated crop, the disease possibly

[1] *Annual Reports of Secretary of Economic Development and Statistics of Foreign Trade*, *1930–31* and *1932–33*.

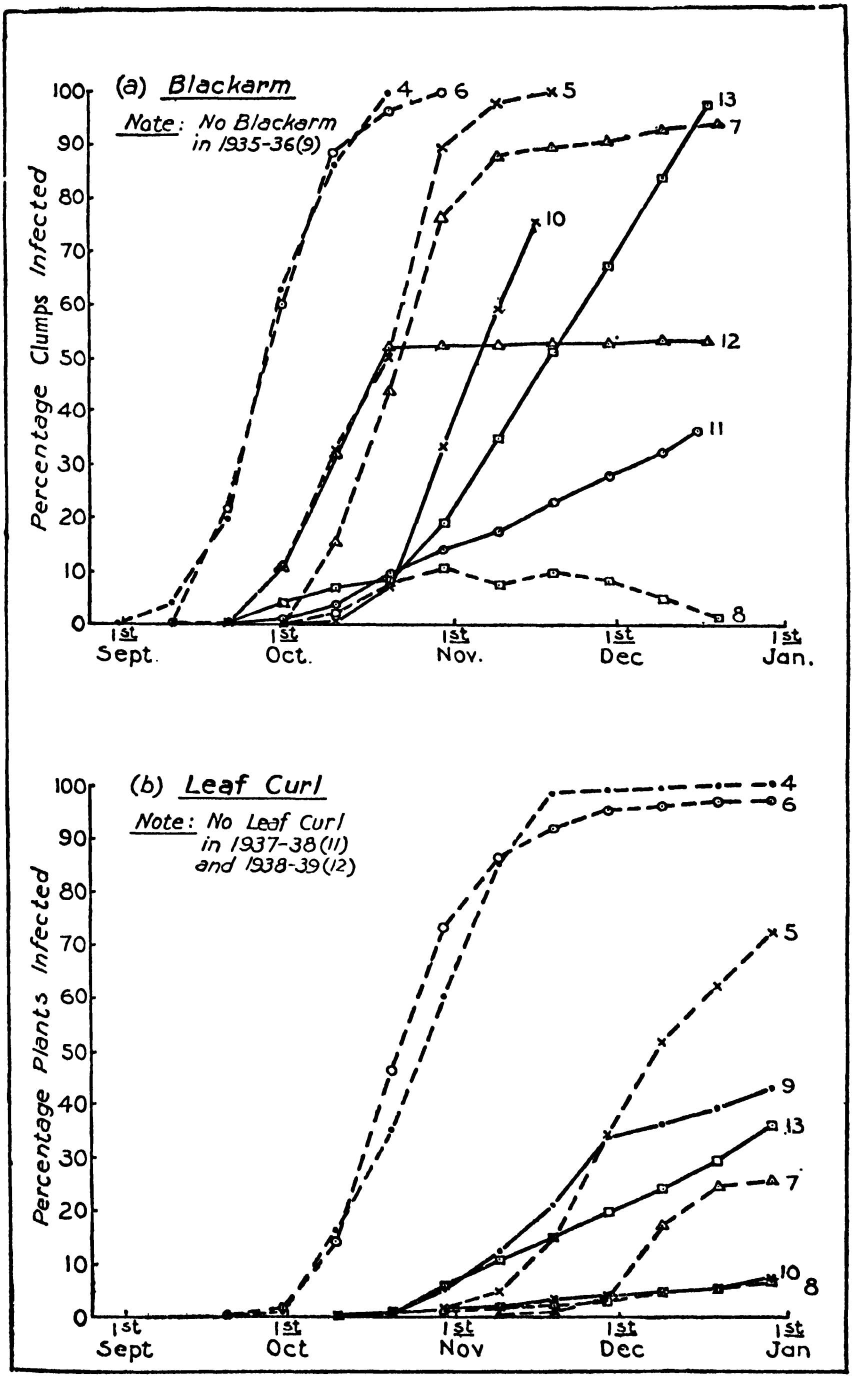


FIG. 215. Graphs showing (*a*) amount of blackarm infection, (*b*) amount of leaf-curl infection in the individual seasons. The data are from the old observation plot (P. 57) at the Gezira Research Farm, started by A. R. Lambert in 1927–8, and the seasons are numbered serially up to the 13th year, 1939–40. No records of disease were kept until the 4th year, 1930–1. The counts were made at fortnightly intervals (F. Crowther, *Ann. Bot.*).

having entered the Sudan earlier in imported cotton seed.[1] The extent to which the severity of its attack varies from year to year is illustrated in Fig 215(*a*), by data from 10 years of the Old Observation Plot.

The disease attacks the leaves first, and the angular moist lesions which follow give the name 'angular leaf-spot' to the foliar stage of the disease. Typical damage to the leaves of a field crop is shown in Fig. 216. These angular areas may amalgamate forming large patches of infected tissue, especially along the veins. The disease may travel down the leaf stalks,

FIG. 216. Cotton-leaves showing blackarm disease at the 'angular leaf spot' stage, as it occurs by natural infection in the field (*photo by M. C. Hattersley*).

or from axillary buds, into the stems, producing the elongated lesions which when old and dry become black, giving rise to the popular name. It can spread from plant to plant by contact between adjacent infected and healthy parts. When severe, the buds and bolls also may bear lesions through infection from the leafy bracts, and the disease may penetrate the boll and attack the developing seeds. Often damaged leaves, branches, flower-buds, and even bolls are shed prematurely, so that the plant stands denuded of its middle and lower limbs, as described in the above quotations. If stem lesions are numerous they may girdle the plant and cause its top to snap off. When seedlings are attacked death may follow and resowing become necessary.

[1] R. J. Arkell states that Merowe, Northern Province, was growing cotton and trading with India through Axum before A.D. 350, and Mumtaz Pasha developed a cotton industry at Tokar and Kassala about 80 years ago; hence the cotton diseases of the Gezira Scheme are not necessarily of recent introduction. —*Editor*.

In November 1922 R. E. Massey identified the disease as *Pseudomonas* (now called *Bacterium*) *malvacearum* E.F.S. This bacterial disease in the leaf-spot stage occurred widely on cotton in the U.S.A., and damage from it was reduced by sterilization of the seed-coats with concentrated sulphuric acid before sowing.

Simultaneously with this identification of the causal organism by Massey at Shambat, A. R. Lambert was conducting field investigations in the Gezira. In the 1922–3 crop at the Gezira Research Farm he made counts which showed that every plant on certain plots was infected by the disease by picking time, continuous cotton being especially prone to attack. Observations made in the early reports of the Sudan Plantations Syndicate Ltd. were confirmed, for Lambert found that later sowings, although producing smaller plants, suffered less from blackarm and gave higher yields. Massey recorded in 1923 that the disease was first noticed on self-sown seedlings, and confirmed earlier observations that plants in virgin soil suffered less than those in old cultivations. He confirmed also observations concerning the benefit of later sowing.

It is remarkable to look back after 20 years of progress in the control of the disease to find that in the early observations of the Sudan Plantations Syndicate Ltd., and in these earliest experimental findings lay the key to effective control-measures. Apart from the breeding of resistant varieties, described in the next section, those in operation at present in the Gezira are:

1. Disinfection of seed by the use of Abavit B, a proprietary mercurial dust.
2. Delayed sowing on land adjacent to that where cotton was grown the previous season, and where rainfall is especially heavy, as in the southern Gezira.
3. Rigorous clearing and burning of cotton debris at the end of the season to destroy diseased material.
4. Destruction of self-sown cotton seedlings.

The first measure is designed to control 'primary' infection, i.e. infection in or on the seed, whereas the rest are concerned mainly with 'secondary' spread, i.e. the infection of healthy seedlings after their appearance above ground. That successful control was not achieved earlier, before the large extension which followed the opening of the Sennar Dam, arose, it would seem, through failure to appreciate the extremely infective nature of the disease and the importance of this secondary spread.

Because of the success in the U.S.A. of seed-disinfection, the entire seed for the 1924–5 crop was dusted with a disinfectant (not Abavit B). Since the resulting crop suffered severely from blackarm damage, it was concluded that the treatment had failed. Moreover, R. G. Archibald claimed that the organism occurred not only on the outside of the seed but inside it, in the cotyledons. These combined results discouraged further field-trials with seed-disinfectants, and efforts were concentrated on experiments to sterilize the seed, both internally and externally, by heat. This preoccupation with internal infection probably arose out of

the deliberate selection for experimentation of material infected very heavily. At that time it was thought that plants, apparently healthy, could sustain internal infection of the tissues of leaf, stem, and fruit, and that the disease appeared externally as lesions only when the temperature and humidity were favourable.

Studying the development of the disease resulting from sowing infected seed, Massey found that the degree of infection of young cotton seedlings was largely controlled by the temperature of the soil, thus:

Soil temperature (° C.)	*Degree of infection*
11–15	Light
16–20	General
21– 6	Severe
27– 8	Less severe
28–30	Light or none
Above 30	None

He suggested that heavy rainfall immediately after sowing, by bringing down the temperature of the soil to about 21°–26° C., produced conditions especially favourable to blackarm attack. To benefit by a higher soil-temperature, therefore, he advocated sowing under as dry conditions as possible, and Lambert had considerable success with this practice in field-trials. Later work, however, has shown that the benefit from dry sowing is not entirely from the higher soil-temperature, for in dry soil there is less opportunity for the mobile bacteria to swim about in the soil-water and infect healthy plants within the same cluster. This is illustrated by the following results of Massey and T. W. Clouston for the percentage of seedlings infected when cotton was sown at increasing intervals after an irrigation, the sample of seeds sown being known to contain a proportion infected with blackarm:

	Percentage of seedlings infected
(*a*) Sown just before an irrigation	10·7
(*b*) ,, 2 days after an irrigation	24·8
(*c*) ,, 4 ,, ,,	9·3
(*d*) ,, 6 ,, ,,	0·3
(*e*) ,, 8 ,, ,,	No germination

Six millimetres[1] of rain fell 24 hours after the sowing of series (*b*), and under those very wet conditions the heaviest infection was obtained. The first lesions were seen to be on the edges of the folded cotyledons, and Massey suggested that in dry conditions the bacteria either could not escape from the infected seed-coat or could not reach the cotyledons before they pushed above the soil, which in the Gezira takes place about 4 days after sowing.

At first, too, rainstorms were considered to encourage the disease by chilling not only the soil but the aerial parts of the plant. This was in accordance with the belief that internal infection of the tissues was widespread in plants apparently healthy, the disease being revealed by lesions only in the favourable conditions of temperature and humidity which produced water-soaked tissues. Massey first noted that driving

[1] 1 in. = 25·4 mm.

rain was important in that it spread the disease by carrying the bacteria from leaf to leaf and from plant to plant, when, 14 days after a heavy storm in October 1928, he found obvious symptoms on previously healthy plants growing down-wind of an infected crop. From then the importance of rain became increasingly recognized as the principal means of spread in the field, both from outside to the new crop and from diseased to healthy plants within it.

With this realization of the importance of rainstorms in the spread of the disease was coupled a change in opinion regarding the relative importance of seed-infection and secondary spread in the Gezira commercial crop. Early work had been based on the belief that most of the damage arose from seed-infection, but this view had to be modified after the complete failure of seed-heating to control infection in the field. Massey had found in the laboratory that heating seed for 2 to 3 days at a temperature of 185° F. did not impair germination but greatly reduced the amount of blackarm on (and probably in) the seed. Yet when a large-scale trial with seed which had been heated was made in 1929–30 on 500 feddans of the Gezira commercial crop, the seed-heating treatment gave no observed differences in the amount of blackarm. As 1929 was a year of exceptionally heavy rain it is probable that extensive secondary spread obscured any differences arising out of seed-treatment; the results focused attention on the extremely infectious nature of the disease.

Another step forward was made when, following his laboratory work, Massey, in 1930–1, modified his views on the greater importance of *internal* infection of the seed, concluding, 'The parasite is borne mainly on the surface of the seed, but internal infection of the seed must not be ignored if the seed has been derived from a heavily infected crop'. Once again he turned his attention to seed-disinfectants, recognizing that earlier results in the field had been vitiated by widespread secondary infection.

This juncture coincided with the appointment of M. A. Bailey as Controller of Research, and thereafter laboratory and field work were closely co-ordinated, the former being concentrated on a study of the bacterium and seed-disinfection, the latter on the conditions and methods of spread in the Gezira. The new knowledge gained on the nature of the disease and on effective methods for combating it is described later.

It is to be regretted that this period of productive investigation did not begin earlier, before the extension of the Gezira Scheme and the alarming deterioration in yields. As early as 1925 it had been noted in the report of the Director of Agriculture and Forests that the introduction into the Gezira of fresh seed from outside, especially from Tokar, the Gash Delta, and Egypt had proved decidedly beneficial against blackarm, yet in subsequent years, although much of the Gezira was sown with seed of various origins, no conclusive differences were revealed, and a considerable area continued to be sown each year with seed from the Gezira crop itself. When the yields of 1930–1 proved the lowest on record it was realized that sweeping changes were urgently needed if the tide of crop deterioration was to be stemmed.

Action could no longer await further experiment or large-scale field-trials. New seed for the entire Gezira crop was purchased from Egypt in 1931, because blackarm was known to be virtually non-existent in Egypt. As an added precaution the whole of this new seed was treated with a poisonous dust, 'Abavit B', by Massey who considered it the most promising disinfectant. For convenience the dust was applied to the seed while it was spread out in a thin layer for 'sunning' to kill pink bollworm larvae (v. Fig. 217). Scant experimental knowledge supported the original choice of Abavit B, but later work has justified its continued use on all

FIG. 217. Dusting cotton-seed with Abavit B. The seed dusted was that to be sown in the Gezira Scheme in 1931–2. It was also being sunned for the destruction of resting larvae of pink bollworm (*Plant Path. Sec.*).

seed sown in the Gezira from that time onwards. Simultaneously with this change in the origin and treatment of the seed, a great effort was made to destroy systematically all self-sown seedlings. To study the spread of the disease on the commercial crop, records were kept by the Sudan Plantations Syndicate Ltd. on blackarm incidence in relation to sowing-date for every field of the Gezira Scheme.

The yield of the first season in which the new control measures were enforced, 1931–2, showed very great improvement, but nevertheless R. Hewison,[1] describing that crop, estimated that blackarm was responsible for the loss of 60,000 to 100,000 kantars of cotton, despite seed treatment and favourable rainfall. He considered that the value of Abavit B was not proved, but it was decided to repeat the seed treatment for another season and to adopt the results of the latest experiments.

In selecting for description the types of experiment upon which the control of the disease in the Sudan has been based, the aim has been to choose the most suitable data, even if the specific example quoted was obtained *after* the practice had been adopted in the Gezira.

[1] R. Hewison, *Empire Cotton Growing Review*, vol. ix, 1932, p. 276.

Seed Disinfection

Abavit B is a proprietary dust which can be scattered over the seed before sowing. It consists of a mixture of mercuric chloride and mercuric iodide with a suitable filler, the presence of the iodide salt greatly increasing its toxicity to the blackarm organism. Its value as a destroyer of primary, i.e. seed, infection was demonstrated in the field by Clouston at Shambat in 1931–2 and in the Gezira in 1932–3, the results obtained in the Gezira being as follows:

Effect of Treatment of Cotton Seed with Abavit B (Cotton sown 1 Aug.; seedlings counted 16–17 Aug.)

Treatment		No. of seedlings with blackarm	Infected seedlings as percentage of total counted
(a) Heavily infected seed (treated with bacterial slime)	Untreated	1,283	25·6
	Abavit B	0	0
(b) Light natural seed infection	Untreated	482	10·6
	Abavit B	0	0
(c) Clean seed mixed with infected ginnery dust	Untreated	557	12·5
	Abavit B	0	0

All the seed treated with Abavit B produced seedlings entirely free of primary infection. Such complete control is exceptional, for usually from the treated seed a very small proportion of infected seedlings is produced; for example, at Shambat in 1931, when seed of the 1930–1 Gezira crop, after treatment with Abavit B, was sown on 12 August, a fortnight later 8 plants showed infection as against 579 plants from the same number of untreated seeds.

Present commercial practice is to use the Gash Delta, where blackarm is rarely severe, as a 'filter' for Gezira seed. Selected seed from the Gezira is sent for sowing in the Gash, and the seed from the resulting crop is returned, much freer from disease, for sowing in the Gezira Scheme the following season. As an additional safeguard the aim is to treat all seed sown in both the Gash and the Gezira by machine-dusting with Abavit B. The dusting is combined, as formerly, with destruction of pink bollworm, but under controlled factory conditions. Laboratory work indicates that, as expected, a liquid disinfectant proves more destructive to bacteria than a dust; for a dust, since it becomes effective only when wetted, does not destroy the bacteria until the seed is sown, by which time some of it may have been shaken off. The use of liquid disinfectants, however, has not yet been attempted on a commercial scale.

Spread by Rain

The secondary spread of the disease by rain can readily be simulated by spraying healthy plants with a dilute suspension of the organisms in water. Clouston obtained the following data from an experiment where infected cotton-leaves, freshly gathered without bruising, were soaked in water for varying periods, the water later being sprayed on to healthy

plants. The latter, when examined after an interval for lesions, produced the following results:

Period of soaking (min.)	*Plants sprayed*	*Plants infected*	*Lesions produced*
5	10	8	11
10	10	9	90
20	9	9	110
40	11	11	Very numerous

Even without mechanical injury to the leaves, under very moist conditions the bacteria exude from the leaves and readily infect other leaves and plants. During rain, liberation of the parasite from a fresh lesion is practically instantaneous, myriads of bacteria escaping from wet lesions. Massey and M. C. Hattersley discovered, however, that, probably because the organisms are carried as powder by wind, they can also be present on the leaf-surface of healthy plants. Infection only occurs when the leaf-surface becomes moist, and then only by the entry of the bacteria through the stomata (breathing pores) or tissues damaged by the rain. Apparently dews are sufficient to supply the moisture, for fresh lesions were found later in the season, when they could not have been caused by rainfall. Clouston found, too, that infection of healthy plants occurred much more frequently by day than by night:

Time of spraying	*Plants sprayed*	*Plants infected*	*Lesions produced*
In daylight (noon)	18	17	161
In darkness (10 p.m.)	20	3	5

The reason for this is, as Hattersley confirmed by experiment, that the stomata open in the early morning and close towards sunset, remaining closed until the following morning. Thus the entry of the bacteria into the leaf tissues at night is more difficult than by day, and therefore, in the Gezira, a rainstorm by day during September and October is more to be feared as a spreader of blackarm than a similar storm by night.

The distance that the disease can be spread by rain was attractively demonstrated by H. Greene in 1932, when, on two occasions during heavy rainstorms, he poured into a small pool a strong solution of fluorescein, which, even in great dilution, can be easily detected. Driving rain proved to have a normal carry of only 5 to 10 yards, but irregular eddies carried drops of the solution as far as 80 yards down-wind. The impact of early rain on bare soil set up a visible spray, but later rain, falling after the soil had grown a cover of weeds, did not. Clouston subsequently followed blackarm spread in the Gezira up to 217 yards from infected seedlings growing on weeded land, but only to 90 yards when similar seedlings were surrounded by weeds. It should be mentioned here that the blackarm organism has never been recovered from the leaf-surface of weeds or of any plant except cotton.

The flat expanse of the Gezira plain, uninterrupted by natural vegeta-

tion or large wind-breaks, and swept by violent rainstorms in September and October, provides conditions exceptionally favourable to the spread of blackarm disease. By contrast, in the areas where cotton is grown on rainfall, as for example in Equatoria Province, the cotton is separated into smaller units, usually by patches of forest and other natural vegetation; and rainstorms are less violent than in the Gezira. R. L. Knight has stressed that in Equatoria Province blackarm is seldom spread long distances by

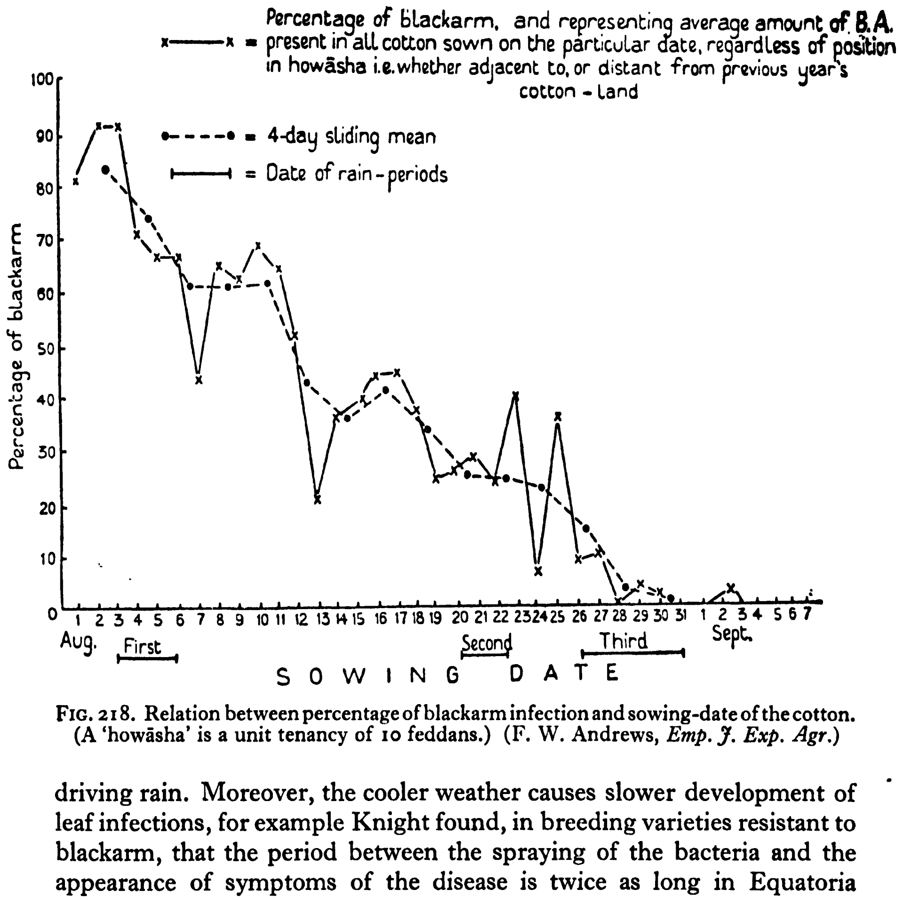


FIG. 218. Relation between percentage of blackarm infection and sowing-date of the cotton. (A 'howāsha' is a unit tenancy of 10 feddans.) (F. W. Andrews, *Emp. J. Exp. Agr.*)

driving rain. Moreover, the cooler weather causes slower development of leaf infections, for example Knight found, in breeding varieties resistant to blackarm, that the period between the spraying of the bacteria and the appearance of symptoms of the disease is twice as long in Equatoria Province as during rainy weather in the northern Sudan.

Effect of Delayed Sowing

One of the quotations from old reports given above showed that it was soon observed that cotton sown early sustained greater damage than that sown later, and by experience it was found that sowings made in July and early August were especially liable to severe attack. Illustrations of this have been given by F. W. Andrews, who made detailed investigations on the spread of blackarm on the commercial crop of the Gezira in 1932-3 and the following seasons. His results, summarized in Fig. 218, were obtained from an examination in mid-October 1933 of 160 feddans of

crop; they amply confirm the wisdom of delayed sowing to combat black-arm attack. Each tenant, as was his custom, sowed a little land at a time, day after day, until his 'howāsha' (tenancy) was complete, and these dates of sowing form a fairly continuous series. As the diagram shows, with sowings made at the beginning of August, the amount of infection was as high as 90 per cent. of the total number of plants, whereas, with those

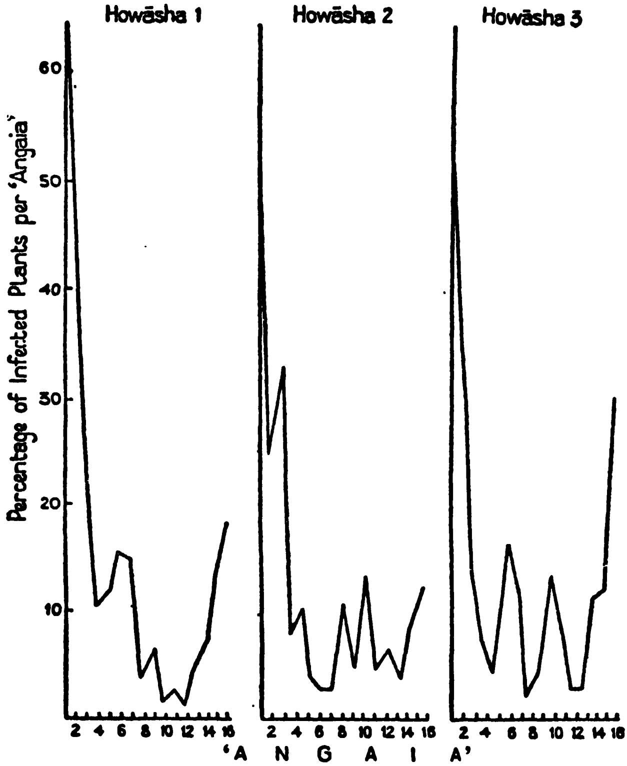


FIG. 219. Effect of the proximity of the preceding year's cotton land on the distribution of blackarm. In all cases 'angaia' No. 1 lies next to the preceding year's cotton land. (An 'angaia' here is one of 16 parallel strips into which each 10-feddan tenancy is divided for the purpose of irrigation.) (F. W. Andrews, *Emp. J. Exp. Agr.*).

made in mid-August, the percentage was reduced to 40, and with those made at the end of the month, to very low values or complete absence. Incidentally since all the seed used by the tenants, there and throughout the Gezira, had been dusted with Abavit B, the results furnished a telling example of the degree of secondary infection prevalent in the Gezira.

The reasons for the diminished infection with later sowings may be summarized thus:

A. *Primary Infection.* From Massey's observations recorded earlier, it follows that, if there should be infection in the seed, the warmer and drier condition of the seed-beds at the later dates would tend to mitigate the resulting attack.

B. *Secondary Spread.* 1. Since the peak of rainfall in the Gezira comes normally in early August, later sowings are exposed to fewer rainstorms and consequently to less danger of spread of the disease by driving rain. The first showers after the crop has germinated may spread infection from debris or self-sown seedlings on to a few plants of the new crop, and thereafter successive showers extend the infection, intensifying the damage on the separate plants and increasing the number of plants attacked.

2. The later the crop is sown, the smaller are the plants at the time of any given storm, and hence the smaller the catchment-area to receive the bacteria and become infected by the disease.

3. As the rainy season progresses the old cotton land becomes well covered either by weeds or by young crops of dura or 'lubia', and rain driving over such land does not carry the bacteria as far as over land bare of cover. Thus with later sowing the area of spread after a storm tends to be smaller.

Infection from Old Cotton Land

In 1931–2 Massey and Clouston discovered that the blackarm organism could survive at least 5 months of desiccation on the debris of old cotton plants at the end of the season; and later work showed survival up to 20 months on woody tissue and boll-cases. Since the dead season between the cotton crops is of only three months' duration, spread is likely, therefore, from infection surviving on the debris itself as well as from seedlings germinated, by rain falling from June onwards, from fallen seed-cotton infected by the disease.

The extent to which the new crop was infected from the residues of the old crop, whether seedlings or debris, was first made clear in field counts by Lambert in 1931–2, who, in a survey of part of the commercial area, gave the following totals for numbers of tenancies in which the new crop was infected, the counts at the Seed Farm being made earlier in the season than those elsewhere:

	Nos. of tenancies on which blackarm was found	
	(*a*) *Adjacent to the preceding year's cotton land*	(*b*) *Adjacent to the preceding year's resting land*
Gezira crop	55	23
Barakat Seed Farm	28	2

The new crop was infected with blackarm much more frequently where it was adjacent to land which had grown cotton the preceding year than where the land had been uncropped. The danger of this old cotton land was generally recognized in 1931–2, and in the following season the sowing-date of the commercial crop was arranged in relation to the proximity of old cotton land, the areas distant from it being sown before those adjacent to it. Andrews, however, found one area of three tenancies, all of which were sown within two days; the distribution of blackarm, shown in Fig. 219, illustrates in a striking manner how the disease

was concentrated on the new crop adjoining the cotton land of the preceding year.

Destruction of Debris

Massey and Clouston found that the organism living on debris, as distinct from fallen seed, could not survive prolonged flooding. After debris had been soaked in irrigation water for 48 hours the infection disappeared completely. This result accords with those obtained when the organism was mixed with wet soil, for in the absence of infected debris it could not be recovered from the soil after 72 hours had elapsed. In dry conditions, however, as in the dust of roads and ginneries, the organism is known to survive for several months. Laboratory work by Massey and Hattersley on this disappearance of the organism in water and in moist soil led to the conclusion that a 'bacteriophage', i.e. a sub-microscopic destroyer of bacteria was responsible. Whatever the explanation, the failure of the organism to survive in unsterilized water or in moist soil was repeatedly demonstrated, thereby giving support to the opinion that flooding of infected debris would be efficacious in destroying infection in the field. Field experiments were therefore started, and Andrews at the Gezira Research Farm in 1933–4 compared 'flooding' versus 'no flooding' of debris. Cotton debris free of seed was spread evenly over the ground and flooded from 16 to 20 July. Cotton was sown on 16 August, and the results from an examination of over 20,000 seedlings were as follows:

	Percentage of plants infected	
	9 Sept.	*24 Sept.*
Flooded 4 days	0·5	2·1
,, 2 ,,	0·4	2·9
No flooding	26·7	69·5

This showed a great reduction in the power of debris to infect the new crop if the debris had been flooded by irrigation water for 2 days; and from other experiments it was found that there was maximum benefit from flooding if the flooding lasted for 4 days. The amount of water necessary to achieve a successful flooding was much greater than the amount the land would normally receive by rainfall before cotton-sowing, and rainfall alone, therefore, was quite inadequate as a means of control of the organisms persisting on infected boll- and stem-debris.

Confirmatory results on the value of flooding were obtained from a large-scale trial on 1,136 feddans of the commercial crop at Seleimi. Part of the cotton land of the previous year was flooded and the average blackarm infection of the new crop adjacent to 17 flooded tenancies and to 17 unflooded tenancies was as follows:

Treatment of old cotton land	*Percentage infection of new crop*
Flooded	5·5
Unflooded	36·6

The large reduction in the amount of infection on the new crop proved that flooding had rendered the old cotton land much less infective. But the benefit could not be ascribed entirely to the destruction of debris, for the flooding had also caused the germination of self-sown seeds left on the ground at harvest, and the resulting seedlings could thus be grazed or otherwise destroyed before the sowing of the crop. Andrews estimated that 400 seeds per feddan remained from a normal cotton crop; the extent to which their germination was hastened by irrigation is illustrated

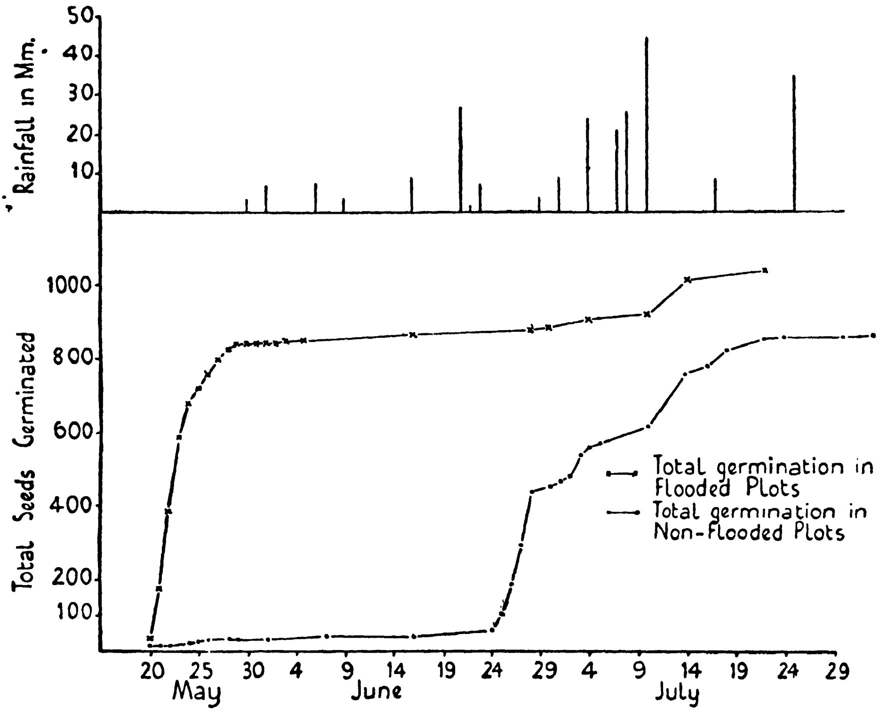


FIG. 220. Germination of seeds enclosed in locks of fallen seed-cotton, under flooding by irrigation and under rainfall. The flooding was given on May 15 (F. W. Andrews, *Emp. J. Exp. Agr.*).

in Fig. 220 from an experiment where known numbers of seeds were scattered over sub-plots and partially buried, to reproduce conditions in the field. Flooding in early May resulted in the germination by the end of the month of most of the viable seed. Under rainfall, there was little germination until the second half of June, and seedlings continued to appear throughout July. In the Gezira, where during the summer months fodder is very scarce indeed, any plants germinating before the rains are likely to be consumed by animals, and therefore, even apart from destroying debris, flooding greatly lessens the amount of infective material, by reducing the number of self-sown seedlings surviving till the sowing of the new crop. Counts made at the Gezira Research Farm in August 1932 reached a total on some plots of 1,800 seedlings per feddan, although the land had been completely cleared of weeds and seedlings by hoeing in July. Infection on these seedlings in some cases reached 8 per cent.

Flooding followed by weeding has also been shown to be good husbandry, at least when dura is sown shortly after the removal of the cotton, but the use of Nile water is restricted from April to June and flooding cannot be undertaken as a general practice. Nevertheless a great effort has been made every year since 1933–4, not only to burn all cotton plants before 1 June to destroy pink bollworm but also to collect from the ground and burn fallen seed-cotton and even small branches and boll-cases, to reduce to a minimum the amount of debris remaining. Grazing also assists in the removal of cotton-leaves, seeds, and, later on, seedlings. Hattersley has shown that the blackarm organism does not survive passage through the alimentary canal of the goat. Natural conditions in the period before the rains, however, tend to encourage the survival of the bacteria on debris in the Gezira, for little rotting takes place in the dry soil and termite activity is slight. Where, as in Equatoria Province, there is a less pronounced dry season, much of the debris, and the bacteria upon it, are presumably destroyed by natural agencies in the interval between crops.

Principal Means of Secondary Spread

To measure the relative importance of debris compared with seedlings as sources of secondary spread to a crop grown from seed free of infection, Andrews arranged small sub-plots of new cotton down-wind from various types of infected material. Details of the treatments and counts of infected plants are given in the following table and the distribution of infected plants is shown diagrammatically in Fig. 221.

Treatment	*Percentage infection of new crop*
A. Lightly strewn with infected debris, no seed-cotton	0·7
B. As above, but debris later removed . . .	0·3
C. Debris disinfected with bleaching powder, lightly flooded	1·2
D. Debris disinfected with bleaching powder, heavily flooded	0·5
E. A few widely scattered cotton seedlings grown and infected by spraying	23·4

The debris was applied on 4 June, the seed in E sown on 2 August, and the seedlings sprayed on 8 and 26 August. Disinfected seed for the new crop was sown on 25 August and the counts were made on 12 October, 10 days after a suitable storm. The results showed strikingly the outstanding importance of seedlings as a source of infection. Recently additional evidence on the importance of seedlings has been given by A. S. Boughey, who noted that the date of the first appearance each year of blackarm on the new crop is closely correlated with amount of June rainfall, the interpretation being that heavy June rains cause extensive germination of seedlings on the old cotton land, some of which survive until late August and then infect the new crop.

In new areas such as come under cultivation with the extension of an irrigation scheme, provided that clean seed were used, no blackarm would be expected, since there would be no old cotton land as a source of infection. Yet observations made in 1936 on the new extensions of the Gezira Scheme at Debeiba and Fawar showed widespread infection.

Andrews and Clouston decided that there the principal source of spread was the introduction by the population of seed-cotton for hand-ginning, a practice already condemned in the control of pink bollworm, infected seedlings sometimes germinating from the discarded seed. Another possible source is the 'dust-devil', a small cyclonic windstorm which collects and transports light debris, but it is doubtful if the organism so carried remains viable long enough to infect the new crop.

Recovery from the Disease

Even though, as a result of the work of Knight and Clouston, new strains of cotton with definite resistance to blackarm are now becoming

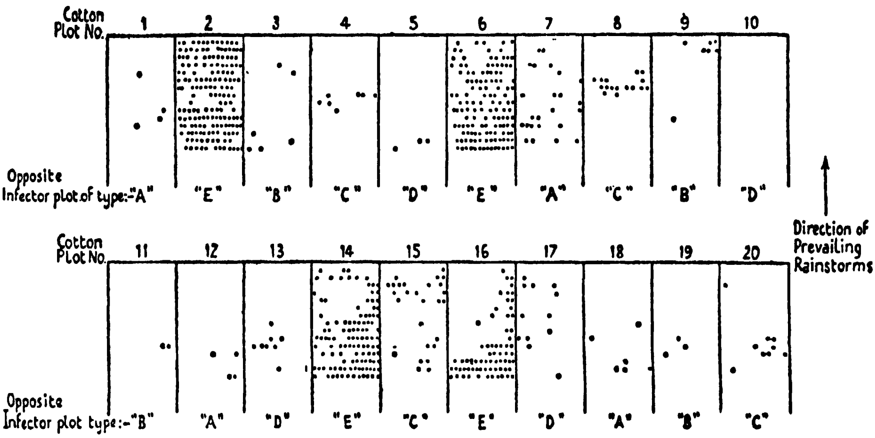


FIG. 221. Distribution of infected plants following exposure to various types of blackarm infection. Type E was infected seedlings. (In the experiment the plots were in a continuous row.) (F. W. Andrews, *Emp. J. Exp. Agr.*)

available for commercial use, the capacity of Lambert's selection of the 1530 variety to recover from the disease after attack was a great asset in that it enabled good yields to be obtained even where blackarm damage had been severe earlier in the season. In addition to these varietal differences, plants lacking vegetative vigour suffer proportionately more damage from blackarm than the more robust ones, for their recovery is less complete, and they do not 'grow away' from the disease. Hence the application of nitrogenous manures, and the introduction of rotations permitting a longer period of rest before cotton, serve to reduce the total damage by promoting more vigorous growth, and must therefore not be omitted from a list of effective control measures.

Procedure in the Commercial Crop

Control measures for combating the disease in the Gezira began in earnest in 1931. Abavit B has been used for disinfection of the seed invariably since that time, but in 1932–3 it became abundantly evident that this measure alone was inadequate. In that year, as a result of the first experiments on the destruction of debris, the *new* cotton land was heavily flooded as soon as water became available in July, to ensure that

neither debris nor seedlings, which had spread from the old cotton land, remained. Moreover, there was a general delay in sowing, especially in areas adjacent to old cotton land. But the following crop proved a complete failure, for the early flooding combined with very heavy rains delayed sowing even later than was intended and the plants also suffered greatly from leaf curl. As a result, the next year there was a reaction against the measures of control indicated by experiments, and the 1933–4 crop was again sown earlier. However, it soon became evident that a planned system of delayed sowing, combined with a thorough clean-up of old cotton land, was sound policy, and this practice was finally established by 1935–6.

Commercial practice in the Gezira has always been sensitive to experimental results, but occasionally the need for control measures has been so urgent that there has been no time for the proper assimilation of the information obtained from them. Results from the small-scale experiments of a research farm often cannot be reproduced exactly in a commercial crop, where conditions are inevitably less rigorously controlled; hence there should always be the intermediate step of large-scale trials. This brief history of the blackarm investigation shows clearly the need for bold planning of experiments, with a multiple approach to the problem, including close examination of conditions in the commercial crop, so that all aspects can be studied simultaneously and the interaction of the factors involved in the development and spread of the disease fully apprehended.

In other parts of the Sudan the disease rarely causes a loss of crop per feddan commensurable with that in the Gezira. At Tokar the crop suffers little damage because it is sown in warm, dry conditions, the rains there coming later. In the Gash Delta early spread by rain is possible, but later the frequent hot, dry winds are believed to help in checking the disease, which rarely reaches severe dimensions.

Archibald in 1925–6 noted that rain-grown American cotton seemed more resistant to attack than the Egyptian types grown in the Gezira. This resistance of American strains, especially of one introduced from Uganda, has been utilized by Knight and Clouston in breeding blackarm-resistant cotton for both irrigated and rain areas. This work, described in a later section, holds out bright prospects that blackarm, already deprived by control measures of much of its sting in the Gezira, may cease to be a major infection of Sudan cotton.

Leaf Curl

In a commercial crop as large as that of the cotton of the Gezira Scheme a new disease is liable to remain unnoticed in its very early stages and to claim attention only after it has spread rapidly and shown obvious effects on the crop. Lambert, who inspected the commercial crop from 1922 onwards, recorded in 1923–4: 'A very small proportion of the plants have been found in various parts of the Gezira showing . . . the leaves and shoots curled . . . and the main stem often flattened and twisted. . . . It does not appear to be of any importance at present but should be kept under observation, and any increase noted at once.' Lambert sent specimens of

FIG. 222. Leaf curl on cotton. Upper portion of plant of Sakel cotton severely infected with leaf curl (*Massey and Andrews*).

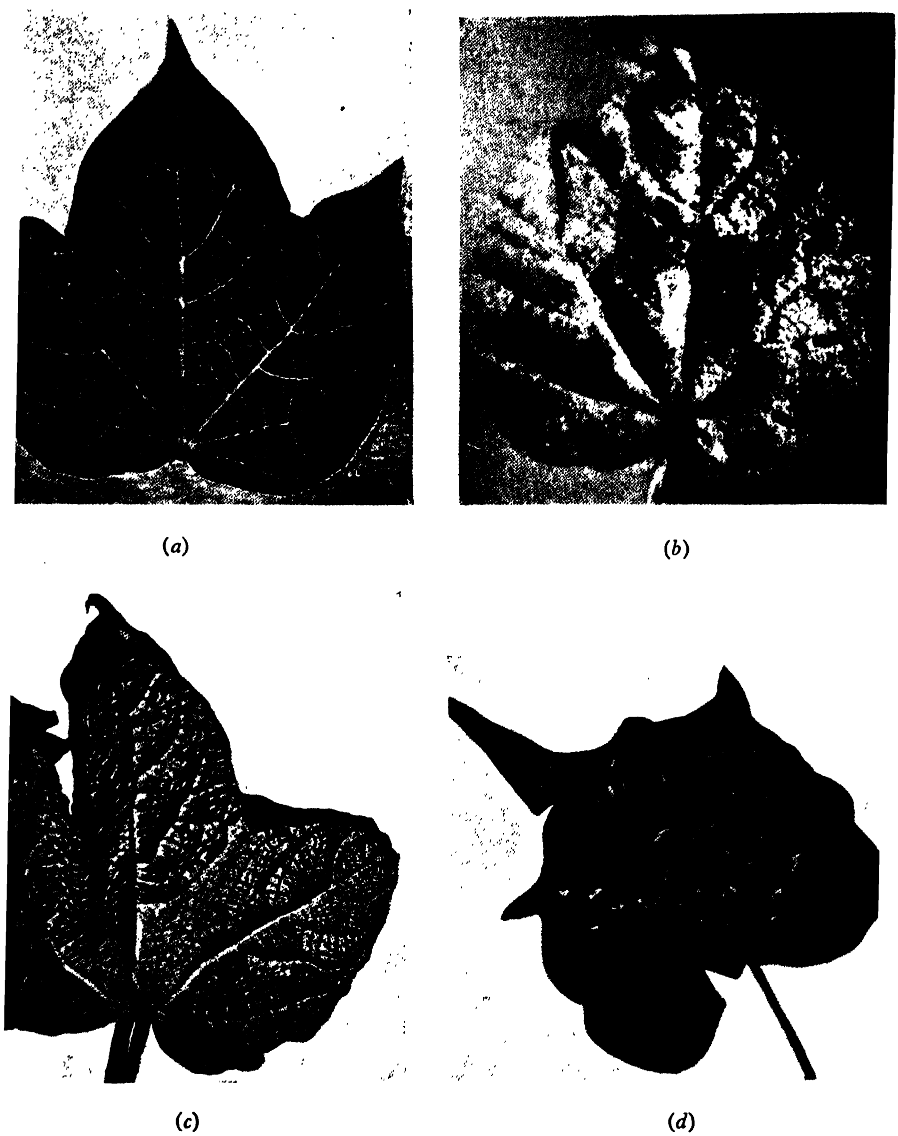


FIG. 223. (*a*), (*b*), (*c*), and (*d*) symptoms of leaf curl on Sakel and at (*d*) on Watts Long Staple American cotton (*photos F. Crowther*).

the disease for identification to Massey who, in later years, confirmed that these 1923–4 specimens were typical of leaf curl. It is thus evident that the disease must have appeared in the Gezira before 1923, but on a much smaller scale than blackarm, which, as described earlier, had become severe before that time.

There is little reference to leaf curl in the annual reports of the next 3 years, when much new land was cropped after the opening of the Sennar Dam in 1925, but in 1927–8 Lambert stated that a marked spread of leaf curl had occurred in that season, whereas in previous seasons only a few plants had been noted. The disease may therefore be included among the factors affecting the yield of the Gezira crop of Sakel cotton from 1927–8 onwards.

A typical specimen of a severely infected plant, given by Massey and Andrews, is shown in Fig. 222, and of infected leaves, by Kirkpatrick, in Fig. 223. The name 'leaf curl' was first applied to the disease in 1925 by H. W. Bedford, and, although this was finally chosen as the official name, the term 'leaf crinkle' is used in early publications by T. W. Kirkpatrick, this name describing more accurately the typical symptoms. A similar leaf curl disease on cotton in Nigeria was described by G. H. Jones and T. G. Mason[1] in 1926.

The first signs of the disease on a previously healthy plant are usually a local thickening of the veins on the underside of the leaf (Fig. 223 *a*) or on the leafy bracts which enfold the flower-bud. In the early stages the thickened veins are most easily detected when the leaf is held up to the sun, for they then appear opaque. As this thickening extends, the leaf gradually crinkles until it resembles that of the savoy cabbage (v. Fig. 223 *b*). Where infection is very severe the leaves curl at the edges and on their underside frequently produce oval, cup-like foliar outgrowths associated with a vein (v. Fig. 223 *c*). The main stem, fruiting-branches, and leaf-stalks show a characteristic bending and spiral twisting (v. Fig. 222), and there is often partial or complete sterility in the infected zone of the plant. The disease has never been observed on the bolls or on the cotyledons. Andrews found that, whereas the juice extracted from the leaves of healthy plants is of a plum-red colour, that from heavily infected leaves is bright green, the colour varying between the two extremes according to the severity of the infection.

The amount of leaf curl has varied considerably from year to year, as is illustrated in Fig. 215 *b* on p. 527, by data from the Old Observation Plot mentioned in the preceding account of blackarm. The disease has never been noted on the new crop before mid-September, and usually does not appear before late September and October. The rapidity of its spread in a field of Sakel cotton is illustrated in Fig. 224 by F. Crowther. This gives the numbers of plants showing external symptoms of infection at successive fortnightly inspections made in 1930–1 on another plot at the Gezira Research Farm. The disease was first noted on 28 September and ten weeks later it had infected 96 per cent. of the plants. The maximum rate of spread was at the beginning of November, and the infection increased from one-quarter to three-quarters of the total crop in a fortnight. In

[1] Jones, G. H., and Mason, T. G., *Annals of Botany*, xl, 1926, pp. 759–72.

years when throughout the main growing-season few plants have appeared infected, a very rapid increase in the number of plants showing symptoms of infection may occur from January onwards, on the 'secondary growth', i.e. the renewed vegetative phase which follows the period of quiescence prevailing during the maturation of the main crop of bolls. If this secondary growth is induced prematurely by vigorous pruning of the plants, the same large increase in external symptoms occurs. These symptoms, therefore, develop in a newly infected plant only in the presence of vigorous vegetative growth.

The loss of crop on the commercial area cannot be determined accurately, for the disease tends to occur most on rapidly growing plants. This association of disease with vigour is illustrated by the following data obtained by Crowther in 1928–9 for the percentage of plants infected by leaf curl, and, as a measure of crop vigour, the final cotton yields, from a range of manuring and watering treatments:

Manuring			*Watering*		
Rate per feddan	*Plants infected with leaf curl (percentage of total)*	*Yield (kantars per feddan)*	*Rate*	*Plants infected with leaf curl (percentage of total)*	*Yield (kantars per feddan)*
Nil	66·0	1·50	Light	68·0	1·88
300 rotls amm. sulph.	79·4	2·41	Medium	82·6	2·35
600 rotls amm. sulph.	90·4	3·02	Heavy	81·2	2·71

At first sight it appears that leaf curl is beneficial to the crop instead of harmful, for the plots where the infection was greatest gave the highest yields! The explanation is that the leaf curl attacked particularly those more vigorous plants produced by the heavier manuring and watering, but, despite the disease, these plants still gave increased yields. When the severity of the attack is correlated in this way with the vigour of the plants it is impossible to assess the loss in crop from the disease by grouping the plants according to degree of infection. Lambert and Andrews overcame this difficulty by comparing the growth of pairs of plants selected early in the season for comparable vigour, one of each pair being healthy and the other diseased. These showed a loss of crop varying from 7 to 84 per cent. In the absence of records from the commercial crop of the proportion of plants infected at successive stages through the season, the results cannot be applied to a crop consisting of an unknown proportion of diseased and healthy plants. Kirkpatrick estimated the loss in the Gezira crop of 1930–1, when the yield proved to be the lowest during the 32 years since the inception of the Scheme, as between 0·5 and 1 kantar per feddan.

The relative loss of crop in the different seasons can be gauged approximately from the rate of spread of the disease, for plants sown around the normal date in mid-August and remaining healthy during October and November probably suffer only small loss of crop, and, when leaf curl is confined to the secondary growth, the loss of crop is likely to be negligible. Sowings made earlier than normal are well developed before the

onset of the disease and so suffer less reduction in yield from it than later sowings which become infected at an earlier stage of growth. Lambert noted, however, that sowings made experimentally during the cold weather, December–February, were only lightly affected.

Following the marked increase during 1927–8, the disease spread even more rapidly through the Gezira in 1928–9, and in some districts most of the crop was infected by the end of the season. Since, only two years before,

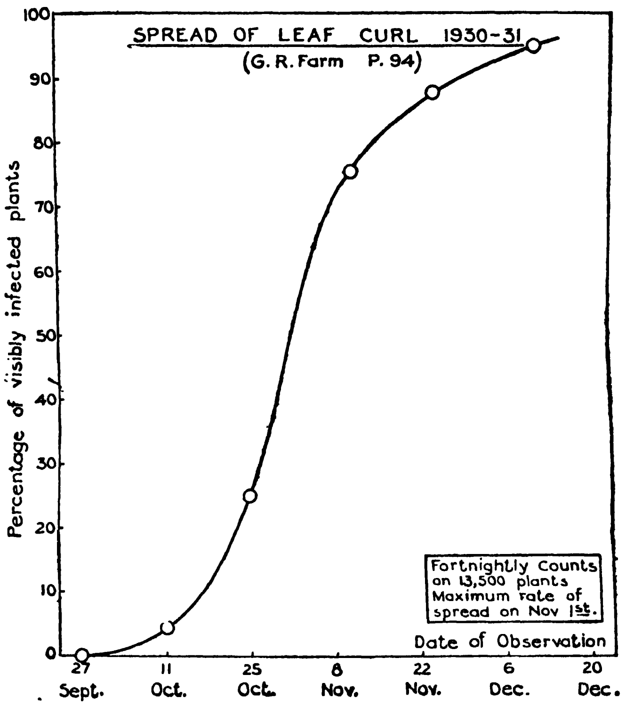


FIG. 224. Proportion of a crop of cotton at the Gezira Research Farm which showed external symptoms of leaf curl (sown 16 Aug. 1930) (F. Crowther, original).

it had passed almost unnoticed, there was great alarm and urgent and effective action was called for. For this reason W. A. Davie, Director of Agriculture, called a meeting of research staff in April 1929 to discuss the emergency and how best to tackle it. From laboratory examination Massey had eliminated bacteria and fungi as possible causes and had concluded that a virus transmitted by insects was probably responsible, but that a physiological explanation, such as mineral deficiency, could not be excluded without investigation. It was therefore decided to examine the alternatives simultaneously.

Soil Abnormality?

It has been demonstrated that vigorous plants more frequently showed symptoms of the disease than weaker ones. Such an association of disease with vigour would be expected if deficiency of an element essential to

growth were involved, for the greater the absorption of nitrogen the more acute would become the deficiency of the limiting element.

To decide whether the soil of the Gezira was responsible, Crowther in May 1929 inspected other areas where Egyptian cotton was grown, with the intention of collecting soil in which to conduct experiments in the Gezira with soil other than that of the Gezira. Unfortunately both the Gash and Tokar were found to have leaf curl, the first record of their infection, and the investigation therefore had to be abandoned. Instead, to make good a possible deficiency, eight minor elements were each applied in solution in the furrows between young cotton plants, but neither in this nor in a later experiment when the same elements were sprayed directly on to the cotton leaves were any differences in amount of leaf curl observed.

B. W. Whitfeild examined the possibility that excessive amounts of sodium nitrite were produced in Gezira soil, and might be found harmful to cotton, but the results were negative. In 1931, at Shambat, O. W. Snow examined two adjacent plots of cotton, one of which showed severe and the other light symptoms of leaf curl. Despite exhaustive tests on both physical and chemical properties of the two soils no differences could be detected; this result appeared to indicate that the soil was in no way responsible for the occurrence of the disease. In 1932 Professor P. Vageler, after visiting the Sudan, suggested that a deficiency of potassium in Gezira soil engendered a predisposition to leaf curl, but with the application of potassium sulphate at the exceptionally heavy rate of 2 tons per feddan, Greene found no alteration in the amount of leaf curl.

A Virus Disease?

Meanwhile much progress had been made towards proving that the disease was caused by a virus. Massey at Shambat had noticed that in 1927–8 white-flies (*Bemisia gossypiperda* Misra & Lamba; Aleurodidae) were the commonest insects in cotton fields where leaf curl occurred, but in 1928–9 he found jassids to be more plentiful. He excluded biting and chewing insects as he considered that these could not adequately infect the plant. Of the insects with piercing and sucking habits the only others which could be considered were thrips and aphis, and these were not present in sufficient numbers or with regularity. He considered that leaf hoppers were the most likely vectors.

Massey noted, in support of a theory of the spread of leaf curl by insects, that the cotton was most infected where it grew alongside a crop of 'bamia' (*Hibiscus esculentus* Linn.) which also suffered from the same disease. In the Gezira the disease appeared worst where cotton grew alongside 'lubia', on which insects abound. Apart from this suspected transmission by insects, the only other method discovered by which a healthy plant could be infected was by grafting a diseased shoot or bud on to a healthy stock, when, three or four weeks after making the union, the stock often produced infected leaves even when grown in insect-free cages. Attempts to transmit the disease by contact or by injecting juice from diseased tissues invariably failed.

Since these preliminary investigations pointed to spread through insects,

Kirkpatrick in October 1929 started a detailed entomological study at the Gezira Research Farm, and his efforts quickly met with success. His method was to grow plants in cages of insect-proof muslin, or in hurricane-lamp glasses with muslin covers. This allowed sufficient light for plant growth but enabled the insect population to be controlled as required.

To demonstrate that the disease did not appear on plants grown in the complete absence of insects, Kirkpatrick grew 40 plants in pots, each caged from the time of sowing until 3 weeks old. At this stage the cages were removed from 21 pots, which were then distributed among cotton plants infected with leaf curl but growing in the field. The exposed plants developed leaf curl as follows:

Period of exposure (days)	*No. of plants showing leaf curl*
16	1
24	6
38	17
87	All

All became infected within 3 months of exposure, yet during this time none of the 19 plants continuously caged developed the disease. To discover what species of insect was involved, he enclosed jassids in pill-boxes clamped on to the leaves of 40 plants, 20 of which were caged to exclude all other insects. The jassids were carefully collected from leaves showing typical symptoms of leaf curl and were allowed to feed on a healthy leaf for up to a week before they were removed. Of the 40 plants examined only 2 developed leaf curl, and both of these had been exposed to other insects. In a second experiment where jassids were admitted directly to 45 cages, each enclosing a single plant, only 1 plant produced leaf curl, and that plant had been accidentally left uncaged for 3 days after the emergence of the seedling.

By contrast with these negative results with jassids, transmissions were readily obtained with white-flies. The latter, collected from infected cotton as described for jassids, were admitted to 32 plants each caged separately and, of these plants, 11 showed typical leaf curl symptoms within 34 to 62 days. As this experiment was conducted simultaneously with the second jassid experiment mentioned above, the evidence strongly favoured white-flies, not jassids, as the principal insect vectors of the disease.

The experiment which finally confirmed the virus origin of the disease and eliminated completely the Gezira soil as a predisposing factor was one conducted by Kirkpatrick with water cultures. Cotton plants were grown successfully in water to which normal nutrient solutions had been added, and were caged as before. In the first experiment, of 9 plants to which white-flies had been admitted, 8 developed leaf curl within 8 to 32 days. In a second experiment 39 out of 40 plants provided with white-flies from infected cotton produced leaf curl. In both experiments there was no trace of the disease on the control plants kept free of insects. Kirkpatrick concluded that white-flies were the main, and probably the only, vector of leaf curl. Subsequent work in the Gezira and elsewhere has abundantly confirmed his conclusion.

In studying the conditions in which white-flies were able to transmit the disease he made a total of 157 successful transmissions to healthy cotton, by means of white-flies, out of 168 attempts. He found that very few white-flies were necessary:

Number of insects per cage	*Successes*	*Failures*
6	1	0
5	1	0
1	3	11

It was possible for a single insect to spread the disease from one plant to another, and the symptoms produced were just as severe as if a large number of insects had been present. Incidentally, this result illustrates that the disease is not caused directly by white-fly damage, but only arises through the medium of the virus.

The many experiments which Kirkpatrick conducted before he left the Sudan in 1931 contributed much to the knowledge of the development and spread of the disease. Whereas young plants when infected tend to develop acute symptoms—an important factor in the amount of damage caused to the commercial crop—older plants may produce either mild or acute symptoms. There is no reason to believe that more than a single strain of the virus is involved, nor that the disease gains in virulence by continuous passage through Sakel cotton. Kirkpatrick transferred it through seven successive series of plants, the last showing symptoms to the same degree of severity as the first. Also there is no evidence that white-flies which breed generation after generation on infected Sakel cotton change in their power to transmit the disease. They can pick up and transmit it as readily from a newly infected plant as from one long infected, but then are unable to pick up the disease from a plant earlier than the day previous to that on which definite symptoms become visible. When white-flies are fed on the apparently healthy leaves of a plant showing elsewhere typical symptoms of leaf curl, the insects can become infective and can transmit the disease. This indicates that the virus is distributed throughout the aerial parts. The time taken by the disease to appear after infection by white-flies is very variable. Thus, in 200 controlled experiments the inoculation period of the virus varied between 8 and 34 days, in two-thirds of the cases the period ranging from 11 to 19 days. The reasons for these large differences are obscure.

All the main experiments were conducted with adult white-flies, but it was found that, even if the insects fed on infected plants only in their larval stage, the adults were able to transmit the disease, which persists in the insect for a long time, probably throughout the rest of its life. It cannot, however, be transmitted through the egg, infected adults apparently laying virus-free eggs. As short a time as 3 hours is enough for a white-fly to pick up the infection, and it can be passed on to healthy plants by a half-hour's feeding. In one experiment the whole infection and transmission were completed within 6½ hours.

Although numerous varieties of American cotton can show, when

infected, the typical leaf curl symptoms already described, some American varieties exhibit completely different symptoms. Thus when Kirkpatrick allowed infective white-flies to feed on the American strain Watts Long Staple, the symptoms produced were, instead of the usual thickening of the veins, a mosaic mottling of the leaves (v. Fig. 223 *d*). This happened in all the 16 transmissions attempted. Later work showed that on rare occasions slight crinkle of the leaves accompanied the mosaic symptoms on Watts Long Staple, whereas on other American varieties, some exhibited crinkle only, others mosaic only. A third group, including a strain earlier cultivated at Rufa'a, Blue Nile Province, developed both crinkle and mosaic together. When Kirkpatrick placed on healthy Sakel plants white-flies infected on Watts Long Staple showing symptoms of the mosaic, no symptoms of the disease appeared. That these Sakel plants became infected, yet for some reason failed to develop symptoms, is shown by their ability to infect white-flies which could transmit the disease to Watts Long Staple, so that mosaic symptoms duly appeared. Such is the complexity of a problem involving a virus disease!

The ease with which the disease can be transmitted by infected white-flies to cotton and other plants is shown in the following table summarizing the principal results of Kirkpatrick, and of J. W. Cowland who continued the work:

Summary of Results of Experiments on Transmission of Leaf Curl by White-flies

1. *From Sakel cotton:*
   (*a*) *Easy to* Sakel cotton, *G. barbadense* Linn.; American cotton, *G. hirsutum* Linn. (symptoms mosaic and/or crinkle); 'bamia,' *Hibiscus esculentus* Linn., cultivated; 'weika,' *H. esculentus* Linn., wild; 'tīl,' *H. cannabinus*, Linn.; 'kerkadē', *H. sabdariffa* Linn.; hollyhock, *Althaea rosea* Cav.
   (*b*) *None successful to* Asiatic cottons, *G. arboreum* Linn. and *G. herbaceum* Linn. (except to *G. arboreum* var. *Nanking*); 'hambūk', *Abutilon* spp.
2. *From American* (*Watts Long Staple*) *cotton:*
   (*a*) *Fairly easy to* Sakel cotton (symptoms masked); Watts Long Staple and other American varieties (symptoms mosaic and/or crinkle).
   (*b*) *None successful to* 'bamia'; 'hambūk'.
3. *From 'bamia':*
   (*a*) *Easy to* 'tīl'.
   (*b*) *Difficult to* Sakel cotton; American cotton; 'bamia'.
4. *From 'weika':*
   (*a*) *Easy to* Sakel cotton.
   (*b*) *Fairly easy to* 'weika'; 'tīl'.
5. *From 'tīl':*
   Easy to Sakel cotton; American cotton; 'bamia'; 'weika'; 'tīl'.

All successful transmissions produced typical thickening of the leaf-vein except on certain American varieties of cotton where the symptoms of mosaic, already described, were exhibited. From okra the transmission was achieved only with difficulty. Kirkpatrick succeeded in 12 out of 16 attempts to infect 'bamia' from Sakel, but never the reverse. Cowland, however, ultimately succeeded in the latter, obtaining in one experiment a rapid transmission of the disease, all 5 Sakel plants showing

symptoms within 3 weeks of infection. Since the disease could be transmitted not only from 'bamia' but also very easily from 'weika', a wild type of the same species (*Hibiscus esculentus* Linn.), plants of either strain, if surviving the dead season of June to August, were considered a potential danger to the cotton crop. The result with hollyhock is interesting because this plant often shows symptoms of leaf curl in Egypt and India where the disease has never been found on cotton.

No success was gained with plants outside the Malvaceae family. 'Lubia', which is exceptionally attractive to white-flies, never suffers from the disease. Failure with tomato (*Lycopersicum esculentum* Mill) is surprising, because this crop in the Gezira suffers from a leaf curl disease, and a foliar outgrowth has been observed on it as on cotton. Work up to the present suggests that the disease is caused by a different virus from that of cotton, yet Cowland found it could be transmitted by the same species of white-fly.

Control of the Disease

Cowland, studying the habits of white-flies in the Gezira, found that, whereas they were plentiful in riverside cultivation and in gardens during the dead season of May and June, they were scarce on the main irrigated tract until August, when they increased rapidly on the convolvulaceous weed 'tabr' (*Ipomoea cordofana* Choisy). This increase was of adult insects and, since extensive breeding had not been found earlier, the inference is that they had migrated from outside on to the 'tabr'. There is some evidence that they first appear on this weed in the south, near Sennar, and that the prevailing south wind facilitates the invasion of areas farther north; but this has not yet been finally confirmed. The insects multiplied rapidly during September and, as the weeds dried off, they migrated to the 'lubia' and cotton. Counts of white-flies made by Cowland in 1933–4 are summarized in Fig. 225, which shows very clearly the rapid increase in the white-fly population on cotton from mid-September till mid-October. A sharp decline followed from mid-November, with very low values in January to March. The decline in numbers was not a result of parasites, and was ascribed by Cowland to the sharp drop in humidity which follows the arrival of the north wind.

In view of the dearth of green weeds in the dead season and of the limited range of cropping in the Gezira, the source of the leaf curl infection on the new cotton crop was at once recognized as being mainly infected ratoons, i.e. new shoots springing from the stumps or tap-roots of old cotton plants which survive from the preceding crop (v. Fig. 226, published by F. E. Kenchington). These ratoons abounded through the practice of cutting out the old crop at ground level, leaving many roots to survive the dead season and send up new shoots in the rains. Where dura and 'lubia' were grown on old cotton land, as in the 3-course rotation, the ratoons were sustained by irrigation and were not grazed by animals. White-flies, which are plentiful on 'lubia', would thus tend to include the ratoon cotton in their diet. Following a season of severe leaf curl a high proportion of these ratoons was usually infected, as a combined result of the relatively high incidence at the end of the season and of the cutting-

back of the plants. An indication of their extent is shown by an examination, conducted at the Gezira Research Farm in August 1932, which

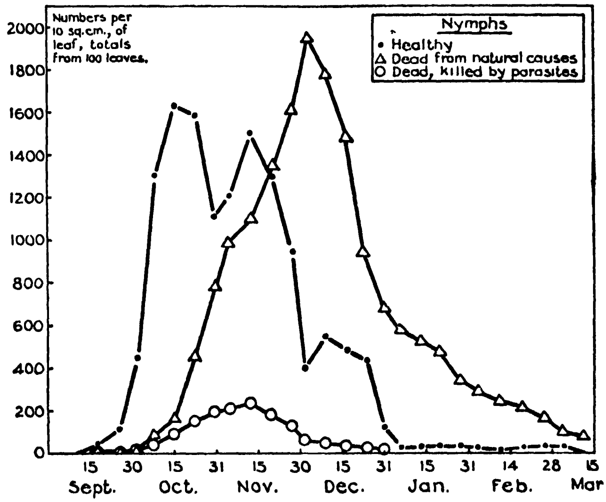


FIG. 225. Numbers of white-fly nymphs on cotton at the Gezira Research Farm in 1933–4, showing healthy nymphs and those dead from natural causes and from parasites (F. W. Cowland, original).

revealed up to 700 ratoons per feddan; the infection by leaf curl was in some cases as high as 70 per cent.

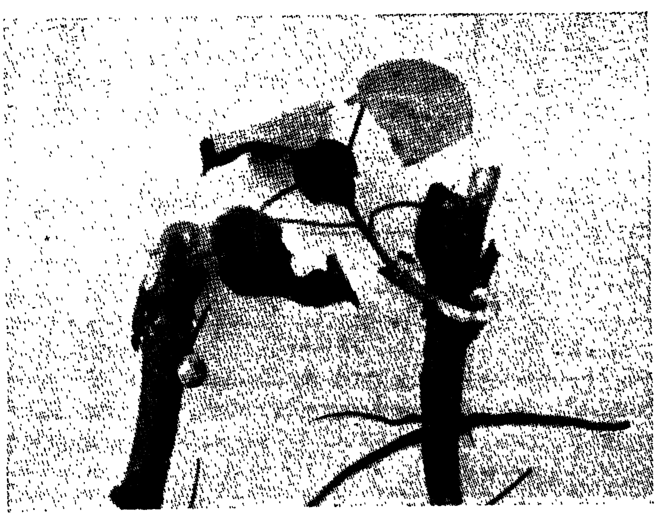


FIG. 226. Ratoon cotton growing from stump after the cotton had been cut at ground-level (after Kenchington).

Of the other hosts, 'bamia' would be the most common were its cultivation between 1 June and 15 September not prohibited by legislation, as a control measure against pink bollworm. As a result of the work of

Kirkpatrick and Cowland, the cultivation of 'bamia', and also of 'tīl', 'kerkadē', and hollyhock, is now prohibited during the same period. Efforts are made to destroy 'weika', especially where it may survive the summer dead-season, as on the banks of irrigation channels, among lucerne, or in gardens.

The only other source of infection requiring examination was cotton seed. In the Gash Delta, for instance, the numbers of infected ratoons alone seemed insufficient in some districts to explain the distribution of the disease. Moreover, leaf curl was recorded for the first time at places as widely distant as Tokar, the Gash, Shambat, and Dueim within a short period, and the only link between them seemed to be the seed used for sowing. But seed-transmission is not common with virus diseases, and many observations did not accord with the theory of spread by seed. For example, the disease never occurred in caged experiments in the absence of white-flies. Moreover, leaf curl would be expected to appear earlier than late September if transmitted in the seed. Nevertheless, the possibility that the seed might carry the disease was an important factor leading to the decision to import seed from Egypt for sowing the entire Gezira crop in 1931–2.

As a direct test on the possibility of seed-transmission Massey and Andrews laid out a small area of cotton at the foot of Jebel Dūd, an isolated hill between Sennar and Kosti, at least 10 miles from any place where cotton had been previously grown and 40 miles from the nearest cotton cultivation of that year. The crop was irrigated from a rain-pool and the seed was especially selected from plants heavily infected with leaf curl. On the 9,000 plants examined in the first year, and the 30,000 plants the second year, there was no trace whatever of leaf curl, even on a single seedling, whereas the commercial crop of the same date had considerable infection. Although the result does not absolutely preclude the possibility that one seed in many thousands may carry the disease, it was decided that seed infection, even if it existed, could be ignored in the Gezira.

Adequate control of the white-flies themselves, by spraying, was found impracticable, so there remained only the more effective destruction of cotton-ratoons, and the growing of varieties resistant to the disease, if such could be found.

On the strength of the clear-cut results of Kirkpatrick's work which, with that of others, stressed the importance of ratoons in the spread of the disease, the rotation of the entire commercial area of the Gezira was changed immediately after the failure of the 1930–1 crop. Temporarily, 'lubia' was omitted and the dura crop was segregated in special areas, away from the cotton land. As a result the land came under cotton for one year and lay uncropped for two, thus ensuring that the ratoons were not irrigated and that those which appeared were accessible to grazing by animals.

The 1931–2 crop suffered only slightly from leaf curl. In that year Cowland gave a delightful illustration of the complexity of seasonal factors, when he noted that the 'tabr' weed was much less plentiful than usual because of the increase in the number of convolvulus hawk-moths; these

completely cleared up the weed while the white-flies were actively breeding upon it. The following crop of 1932–3 again suffered heavily from leaf curl, to some extent because it was sown late. At the time the difference in incidence between the two years was ascribed to the heavier rainfall and the very abundant white-flies of the latter season, but recent observations suggest that another relevant factor was the vigorous root-systems left by the 1931–2 crop which ratooned more readily than those of the previous year.

To avoid ratoons by pulling out the roots by hand, instead of cutting the stems at ground level, was an impossibility; so, to meet the urgent need,

FIG. 227. Root-puller designed to remove cotton plants with their tap-roots (*photo F. Crowther*).

Massey experimented with root-pullers on the 'pincer and lever' principle, and succeeded in producing a tool which, after modification, was manufactured in large numbers by the Sudan Plantations Syndicate Ltd. This tool is illustrated in Fig. 227, which shows the pulling out of an experimental plot at the Gezira Research Farm. The removal of every individual plant by this method seemed a truly Herculean task, for on the commercial area each tenant with a 10-feddan holding had to extract between two and three hundred thousand plants. Yet the method succeeded and the whole of the 1932–3 crop was pulled up by the roots; and every crop since, as well as the Sakel crop in the Gash Delta, has been similarly uprooted. A few plants break in the process and ratoons may result, but in such greatly reduced numbers that by this single measure the disease 'which once threatened to destroy the whole Scheme as an economic proposition'[1] was adequately checked.

The disease still persists locally on the Sakel areas, spreading much more slowly than formerly. It is no longer considered anywhere a major

[1] K. D. D. Henderson, *Survey of the Anglo-Egyptian Sudan, 1898–1941*.

factor affecting yield. Some of these areas, investigated by A. S. Boughey, showed infection on the north side of gardens. Two possibilities are being examined.

(*a*) There may be host plants, associated with gardens, which are still unrecognized. Recently an ornamental shrub, *Malvaviscus* sp. introduced from India in 1936, has been added to the list of alternative hosts, and may have encouraged continuance of the disease at the Gezira Research Farm. A weed, *Sida spinosa* Linn., is suspected, but it has not yet been proved that this plant carries the disease.

(*b*) The attraction of white-flies to cotton sheltered from the south wind which prevails until October may have been an important factor in determining the distribution of the disease. A crop of dura is at times sufficient shelter to attract white-flies to cotton growing on its lee side. The results of three seasons' work by S. H. Evelyn on his leaf-curl resistant varieties (v. next section) indicate that on his plots the spread of the disease during an attack followed the direction of the prevailing wind.

While the progress of the disease was successfully stemmed by the measures described, a second line of control rapidly became available by the development of resistant varieties. These are now grown on a half to two-thirds of the commercial area, the susceptible Sakel variety on the rest suffering but mild infection by virtue of the control of ratoons. These varieties will be described later. Their resistance is all the more remarkable in view of the large number of plants of other species which are susceptible to the disease. As early as 1928–9 Lambert, among his selections from Egyptian cottons, noted differences in resistance to leaf curl. The following data of M. A. Bailey give the degree of infection in a variety trial conducted in the Gezira in 1932–3:

	Percentage of plants infected
Sakel	91·5
X1530	3·0
X1730	2·0
X1030	2·0

Thirty times as many plants on the Sakel plots showed the disease as on the others. To show how fickle is this resistance, the results of a replicated experiment made by Knight at Shambat in 1940–1 may be compared with the one above:

	Percentage leaf curl
Sakel (Massey's S. D.) .	48
X1730A	71

Under the conditions of the Shambat experiment Sakel proved more resistant to leaf curl than X1730A, the more resistant variety in the Gezira. But even in the Gezira the high resistance is not invariably obtained, as is shown in the following results from a replicated experiment

comparing six sowing dates of X1730A at the Gezira Research Farm in 1939–40:

Date of sowing	*Percentage leaf curl at end of March*	*Date of sowing*	*Percentage leaf curl at end of March*
1 Aug.	0	10 Sept.	32·9
13 Aug.	0·03	24 Sept.	38·8
27 Aug.	0·06	8 Oct.	21·5

The resistance is less with late than with early sowing.

These results stress the need for numerous tests under conditions of commercial cultivation before conclusions about the resistance of the different varieties in each district can be accepted as final.

Wilt Disease of Cotton in the Gezira

Wilt diseases of cotton are common in many parts of the world, and one, caused by the fungus *Fusarium vasinfectum* Atk., was widespread among Sakel cotton in Egypt about 15 years ago. In the Gezira area of the Sudan, Sakel and other varieties of Egyptian cotton suffer from other wilt diseases. Some of these attack the plants at the seedling stage, and one, which is very widespread and which attacks older plants, has been the subject of considerable investigation, as the following account will show.

The name 'wilt' describes the loss of the natural turgidity of the leaf-tissues and the consequent drooping of the leaves which are symptomatic of the disease. The leaves turn a dull greyish, or yellowish, green in colour and may even shrivel. In some cases the flower-buds too succumb, and in very severe ones the stems, branches, and sometimes entire plants die. Partial, and indeed complete, recovery from mild wilt is common.

In 1922–3 Lambert recorded: 'During October and November and to some degree in December, individual plants at the Gezira Research Farm, here and there, were observed to be wilting and dying. Strong plants were often affected. The losses at one time were becoming serious but they decreased after this period.' This appears to refer to typical wilt, yet during the next 10 years there were but few reports of appreciable losses from wilt, except in sowing-date experiments. Of these Lambert mentioned that severe attacks occurred in early November on cotton sown in September in both 1931–2 and 1932–3, death of plants reaching 30 per cent. of the total number in the latter season.

In 1933–4 Massey, summarizing the state of wilt in the Gezira, recorded that, although the disease accompanied by a fungal invasion of the root system had been detected yearly towards the end of October, the mortality caused had never been high enough to distract attention from the more urgent problems of blackarm and leaf curl. However, that very year the losses proved more serious than previously, and the disease received close attention for the first time.

A survey of the Gezira by Massey and Clouston showed that wilting and dead plants were found in many areas, especially low lying ones, but were rare in the north. At the Gezira Research Farm wilt was widespread, but varied greatly in intensity from one part to another. Greene found it

to be associated with unusually high alkalinity of the soil. No obvious cause of the wilt was apparent from examination of the aerial parts of the plant, but exposure of the root-systems, by means of a water-jet to wash away the soil, revealed extensive discoloration and death of the fine roots; and in severe cases of wilt the larger lateral roots were rotted as well. Since this happened at a time when the plants were carrying abundant leaves, the cause of the wilt disease clearly lay in the destruction of roots. Laboratory experiments showed that the discoloration, or browning, of the fine roots, noted in the field, could be induced in sand-cultures by adding either extracts of Gezira soil or sodium carbonate; rotting of roots could be induced by stronger solutions. The fungi isolated, with the exception of those known to cause the other wilt diseases, proved reluctant parasites unless the roots had previously been damaged by excessive soil alkalinity.

Accordingly Massey suggested that an extensive invasion of the root-system by soil fungi from late September onwards might be normal in the Gezira on account of this high alkalinity. Wilting and death of plants were the result of an exceptionally severe invasion, and the damage, varying in extent from year to year, could be sufficient to cause appreciable loss of crop over the whole Gezira. He suggested that wetness of the soil, following heavy rainfall, favoured invasion by a fungus which he thought might be a species of *Pythium*.

Clouston, in 1934–5, began a detailed examination of the wilt problem, the results of which are summarized below. In his description of the root-system of cotton he differentiates between the 'fine' roots, which are the thin white ones, with apical root-hairs, whose function is the absorption of water and nutrients, and the 'secondarily thickened' roots, possessing an outer cork layer, which serve as pipe-lines to pass the water and nutrients, absorbed by the fine roots, into the tap-root and so to the aerial parts of the plant. Early in his investigation Clouston found that death of both fine and thickened roots, and also of tap-roots, could occur in the absence of fungi; yet, lest they might have an important, if only secondary, role, the isolation from roots and identification of fungi were continued annually for the next five years.

Distribution of Wilted Plants

Experiments in the field involving a wide range of treatments revealed differences in amount of wilt incidence. The variety X1530, except in 1936–7, was more resistant to wilt than Sakel, whereas XH1229 was much more susceptible than either. Resting the land instead of growing a crop of dura or 'lubia' tended to reduce wilt. The addition of nitrogenous manures increased wilt, except again in 1936–7 when the reverse happened. Spacing results were contradictory, but an increase in the number of plants per hole appeared to reduce wilt. More wilt occurred with light than with heavy waterings. All these differences were, however, small compared with those from intrinsic soil differences, and the tendency of wilt to be more frequent in low-lying areas and on soils especially alkaline and impermeable was confirmed. In any one area, too, although the cultural treatments were standardized, the amount of wilt varied

considerably from year to year. Clouston mentioned that the proportion of plants affected, including those which showed symptoms for a few days and then recovered, reached, on parts of the Gezira Research Farm, 38 per cent. in 1935–6 and 70 per cent. in 1936–7. In some seasons, on the other hand, only a negligible proportion of the plants suffered from wilt.

Recovery from Wilt and the Effect of the Disease on Yield

An indication of the capacity of cotton plants to recover from wilt is given in Fig. 228, describing data collected in 1935–6. A heavy outbreak

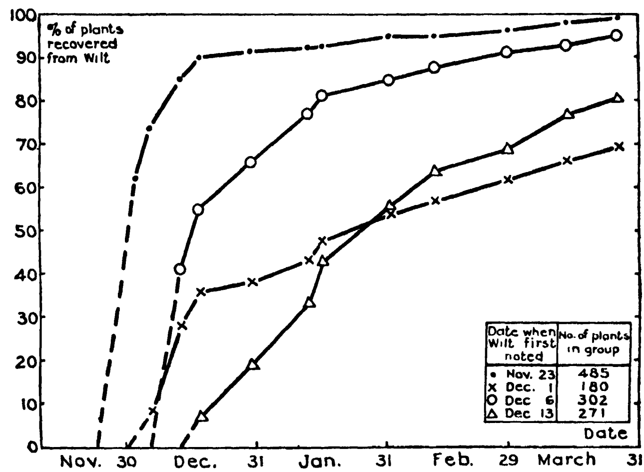


FIG. 228. Recovery from wilt disease. The curves show the percentage of diseased plants which recovered, for four groups, each group consisting of plants which showed the first symptoms of wilt on the same day (T. W. Clouston, original).

occurred in late November and early December, but usually the affected plants recovered quickly from the attack. Clouston suggested that wilting was merely the final expression of a diseased condition from which a very high proportion, if not the whole, of the crop suffered to a greater or less extent. Examination of the root-systems, the results of which are described later, showed that recovery was usually associated with the production of a new crop of fine roots in the top layer of soil. Since recovery could be induced by removing some of the lower leaves to reduce water-strain, it was obvious that wilting occurs as a result of a derangement of the balance between the root-system and the aerial parts of the plant. In the case of a gradual loss of roots, occurring early in the season and unaccompanied by the sudden increase in transpiration (loss of water from the aerial parts), the plant may adjust itself to the loss of roots by shedding some of its leaves and flower-buds, but a sudden derangement of the balance is likely to cause a sudden attack of wilt, such as that illustrated in Fig. 228.

Loss of crop from the disease is therefore difficult to determine precisely since, in the case of a gradual loss of roots, the plants would be

classed as healthy, whereas in reality they were suffering from a masked form of the disease. In a comparison of plants showing visible wilt with others apparently healthy, Clouston in 1936–7 selected pairs of plants, both of equal size but one healthy and one diseased, growing under as similar conditions as possible. He recorded the yields as follows:

	Yield weight of seed-cotton (g.)
(*a*) 50 plants which wilted in early November and recovered before the end of November	868
(*b*) 50 plants which wilted in early December and recovered before the end of December	838
(*c*) 50 control plants which had not wilted up to 21 December	1,163

These results indicate a loss of yield from diseased plants of 34 per cent. when the wilt occurred in November and of 39 per cent. when it occurred in December. The quality of the lint of the wilted plants was lower and the seeds were smaller. The loss of yield in terms of the whole crop depends, of course, on the proportion of plants diseased.

Root Invaders

As part of the investigation Clouston systematically isolated, grew on artificial media and identified, fungi from cotton roots. In five years the number of fungi exceeded 2,000 from fine roots and 300 from thickened roots. In general, the same types of fungi were found in the roots each year, but during the period the numbers of fungi tended to decrease, as did the wilt also. Thus, for fine roots, whereas in 1935–6 fungi were obtained from 65 per cent. of the root-pieces examined, in 1939–40 they were found in only 14 per cent.; and there was a similar falling off in the numbers for thickened roots.

In the fine roots the commonest fungus was one labelled provisionally 'XT', pending identification. *Pythium* spp. were obtained mostly at the beginning of the season and from the top soil, whereas *Rhizoctonia* spp. were usually recovered later, and from roots in the lower soil. As discovered in the preliminary work, none of these fungi appeared to explain wilt incidence without some predisposing cause. In pot experiments designed to reproduce a wide range of soil conditions, *Rhizoctonia* spp., associated particularly with thickened roots, were found capable of producing a rot sufficient to cause wilting and death in seedlings, but none of the fungi isolated induced wilt in fully grown plants. In addition to these fungi, cotton mycorrhiza[1] was found in the fine roots within a fortnight of sowing, abundantly in young healthy roots but decreasing as the roots aged.

The Root-system

As the investigations progressed it became increasingly evident that the role of fungi was indeed only a secondary one, and that a solution of the problem of wilt required a study of the root-system in relation to those

[1] Association of a fungus with roots of a higher plant, probably with mutual benefit.

soil changes which affect root growth. Little was known of the root-system of the cotton plant in the Gezira at this stage, and Clouston devised a new method of root excavation whereby many of the fragile fine roots, lost with the old water-jet method, could be recovered. The cotton was sown at a regular spacing and kept free of weeds. Six plants were sampled at a time, fortnightly from sowing. The soil was excavated in 3-in. horizontal layers and mixed with water, and the roots were separated by sieving into 'fine' and 'thickened'. These, after sampling for microscopic examination and for fungi isolation, were oven-dried and weighed. Records were kept of the development of the tops of the plants.

The distribution of fine roots with depth, at the period of maximum plant development, is shown diagrammatically in Fig. 229. In general, the root-system grew downwards at a rate comparable with that of the elongation of the main stem above ground. The roots reached their greatest depth at the time when the plant reached its final height. As shown in Fig. 229 (*a*), the new leaf-curl resistant varieties, as represented by X1530, possessed a larger system of fine roots than Sakel, but in both varieties the fine roots were fewer at a depth of 1½ to 2 ft. than above or below that depth. This was where they encountered the layer of especially impermeable soil general over most of the Gezira at varying depths. Thus, although the amount of fine roots reached a major peak at 9 to 12 in., there was also a subsidiary peak in the third foot of soil. Comparing root distribution in November and in late January, it was found that in November fine roots were abundant in the first foot; by January they were greatly reduced; and more fine roots had been formed lower down, especially with X1530.

The development of fine roots appeared to suffer a check in November or early December, simultaneously with that to leaf-development, from the diversion of food-reserves to the developing fruits. This was confirmed by an experiment in which the maturation of the plants was delayed by removal of the flower-buds as they were formed. Clouston records that in these plants the root-systems continued to increase in size, and that many more healthy fine roots were found at all depths than in plants allowed to mature normally. The rate of root mortality and the degree of fungal invasion were not, however, affected by the removal of the flower-buds.

Thus it happens that, in November and early December, when the water requirements of the crop are especially great, partly on account of the strong, drying wind and high day-temperatures, and partly because of the abundant leaf-growth which is then at its maximum, the plant in the Gezira soil fails to develop enough fine roots to replace those lost by normal mortality; the resulting water-strain becomes visible in a mild wilting of the leaves at midday when transpiration is greatest. This condition does not constitute wilt disease proper, but it demonstrates the small margin of safety in the plant's water-economy, and suggests that any further damage to the remaining roots would quickly cause wilt disease.

In root-pruning experiments, when Clouston, in December, severed all the lateral and fine roots down to a depth of 16 in., leaving only the

tap-root to connect the lower roots with the top of the plant, there was some shedding of fruits but the plant did not die. On the other hand, when he left intact surface roots and soil and severed the tap-root, death resulted whenever the cut was eighteen inches or less from ground level. Clearly the plants in December rely mainly on the roots below 18 in. for their water-supply, and this suggests that wilt, which normally occurs in November and December, is caused by inactivation of the roots in the subsoil rather than of the fine roots growing nearer the surface. He considered therefore that any treatment which encouraged the development of surface roots would render the crop less dependent for water-supply on those subsoil roots which are attacked by wilt. Testing this hypothesis in an experiment made in co-operation with G. B. Portsmouth, he found that heavy watering tended to restrict the root-system to the upper soil layer [v. Fig. 229 (*b*)], and that counts of wilt incidence taken in the field showed less infection with heavy than with light watering.

Factors responsible for Wilt Disease

Massey's early suggestion that there was in the Gezira each season from September onwards a progressive invasion of the root-system by soil-fungi, the degree of invasion being at least partially responsible not only for the amount of wilt disease but also for the average yield of the whole crop, has not found support in later work. In 1938 Sir E. J. Butler, F.R.S.,[1] put forward an hypothesis that this Gezira wilt arose through the presence of toxins in the upper soil which were leached downwards towards the impermeable layer where they damaged the apex of the root-system, causing the plant to wilt. Recovery ensued when the roots grew beyond this layer into more permeable and less toxic soil below.

Clouston examined this last interpretation by growing plants in a series of pots filled with soil collected in successive layers from the top downwards, and in sand watered with extracts of these soils. He found no evidence of toxins other than sodium carbonate, already mentioned; the impermeable layer was no more toxic than the rest. Instead, Clouston suggested that the restricted rooting in the impermeable layer (v. Fig. 229) arose not from its chemical composition nor from the presence of toxins but from its physical character only. This hampered water movement and consequently the replacement of oxygen and the removal of root-secretions and by-products of the activity of micro-organisms. Wilt, he concluded, occurred when the communication between the fine roots and the aerial parts of the plant was interrupted by rotting of the thickened roots in the impermeable layer. This disintegration alone could cause wilt in the absence of fungi. Yet, under certain conditions, fungi of the *Rhizoctonia* group penetrated the rotting roots and caused further interruption in the water-supply. It was observed that wilt was most severe and plant mortality greatest where the number of fungi recovered from the rotted, thickened roots was highest. Wilt incidence, and

[1] *Note on Cotton Wilt*, presented to the London Advisory Committee on Agricultural Research in the Sudan.

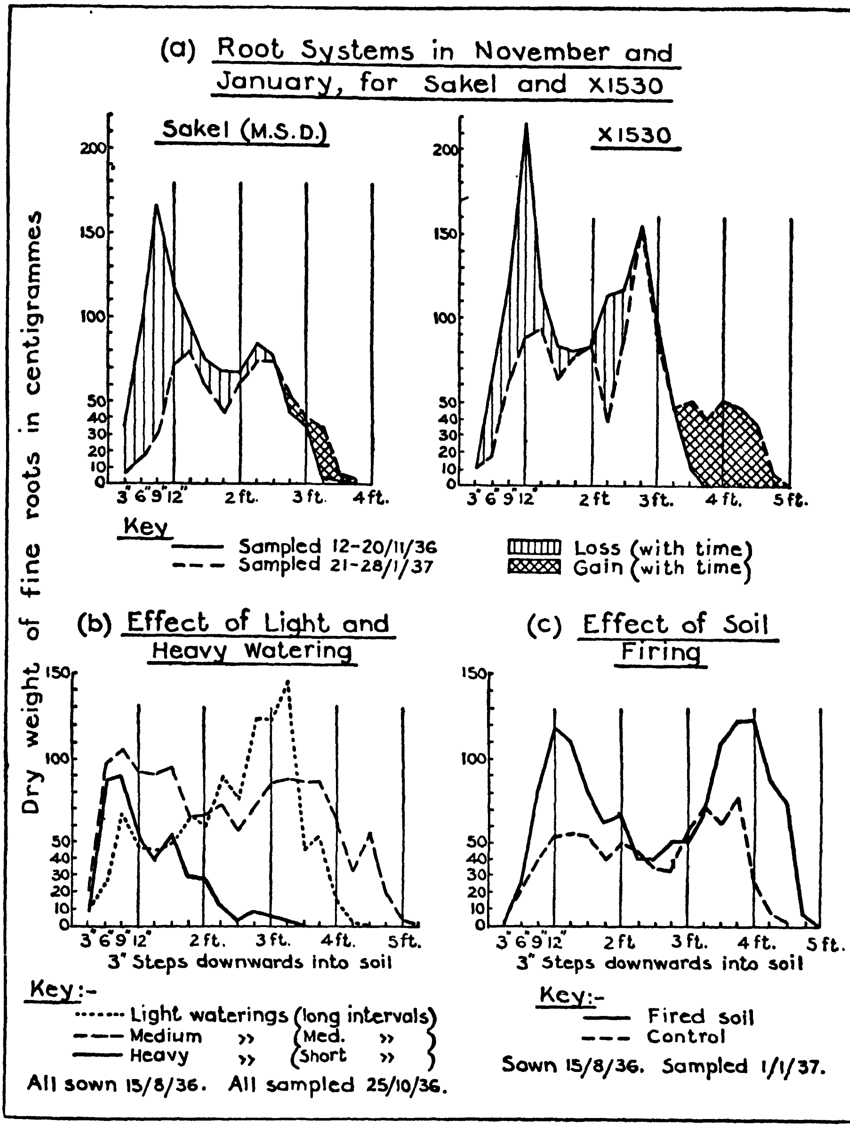


FIG. 229. Distribution of cotton-roots with depth at the Gezira Research Farm, for comparison of (*a*) two varieties, Sakel and X1530, in November and in January; (*b*) three amounts of irrigation, obtained by alteration of the interval between successive irrigations; and (*c*) fired soil with normal soil (T. W. Clouston, *Ann. Rep.*).

especially death of plants from wilt, declined as the numbers of fungi decreased.

A. S. Boughey subsequently put forward the hypothesis that this wilt disease in the Gezira is entirely physiological, the presence of fungi in the roots being incidental to the disease. He suggested that wilt follows from a combination of abnormally hot weather and deficient soil-moisture at the time of crop-maturation when root-production is curtailed. As the crop develops, from October onwards, a gradual drying-out of the lower soil-layers takes place because the roots absorb more water than is replaced

FIG. 230. Casts made by termites while consuming hoed weeds among young cotton plants (*photo F. Crowther*).

by succeeding irrigations. If hot weather occurs later than usual, the roots, whose production has been curtailed by the maturation of the crop, may fail to maintain a rate of water-supply sufficient to replenish the loss from the leaves. Different intensities of the factors involved in this combination, he suggested, could account for the varying amount of wilt in the Gezira from year to year, and the proportion of deaths to recoveries among affected plants. The varieties X1530 and X1730, which normally mature a fortnight later than Sakel, suffer less from wilt because they mature in cooler weather. In support of this contention he noted that, when in 1936–7 hot weather occurred abnormally late, the order of the varieties in resistance to wilt was reversed, X1730, not Sakel, suffering by abnormal water-strain. Moreover, nitrogenous manuring, by increasing the amount of leaf-growth without correspondingly increasing root-growth, usually produces more wilt disease.

A possible association of wilt with termites must not be overlooked. From the earliest years termites, which are very active in the Gezira soil (v. Fig. 230), have caused wilting and death of young cotton-plants by eating into the base of the stem or into the tap-root (v. Fig. 231). Usually

the total loss in yield of the crop from this cause is small. Recently Crowther and H. W. B. Barlow have shown that, at the Gezira Research Farm, additional to this *death* of plants about one-third of those plants which survive to form the crop of the farm, including those of all field experiments, suffered severance of the tap-root while the plants were still small enough for the thickened roots to take over the function of the tap-roots and avert wilting of the leaves. This occurred in each of the five years examined. Tap-roots of plants extracted by root-pullers at the end of the season and showing this severance are illustrated in Fig. 232. Such destruction of

FIG. 231. Cotton plants—healthy and killed by termites (*photo F. Crowther*).

tap-roots, and presumably also of some thickened roots, could facilitate the entry of fungi and lower the capacity of the plant to absorb water. Wilt is usually less severe in the northern Gezira than elsewhere, less after an uncropped period than after dura or 'lubia', and where there are many plants per hole instead of the normal two or three. All these are consistent with the known activities of termites. In 1933–4 both wilt disease and loss of stand from termites were more severe than usual. In recent years there has been less wilt and, since the rotation contains more resting land than formerly, there will probably have been less termite activity. Thus a general nibbling of the thickened roots by termites may further hamper the root-systems of the cotton plants in the Gezira in their function of satisfying the water-demands of the tops.

Importance of Soil Conditions

Clouston not only attributed the rotting of thickened roots to the adverse physical condition of the impermeable layer of soil, but suggested that conditions, similar but less acute, might obtain in other layers and affect the longevity of individual fine roots and the development of the root-

system as a whole. Since these conditions might vary from year to year Clouston saw in them not only an explanation of the wilt problem but a possible explanation of the annual fluctuations in the cotton yields of the Gezira as a whole. Of the many experiments he made to study the effect, on wilt disease and on yield, of alteration in soil-permeability to water, probably the most interesting are those on the firing of soil. It had been found at Indore, in India, that firing a surface-layer of soil improved the yield of cotton sown subsequently in that soil, and Clouston tried this in the Gezira.[1] A surface layer of soil was collected, usually in May, from the land to come under cotton the following August, and was fired by igniting heaps composed of alternate layers of soil and dry cotton-sticks. The method is illustrated in Fig. 233, which shows the fires burning in the background and the fired soil already prepared in the foreground and left side. This soil is later returned to the plots. An early experiment using a 6-in. layer gave an increase in cotton yield of 25 per cent. Later, in large-scale experiments carried out by E. R. John, in which only a 1-in. surface layer was fired, the increases in yield were even larger:

	Yields (kantars seed-cotton per feddan)		
	1937–8	*1938–9*	*1939–40*
Normal	4·05	3·62	3·75
Soil fired	6·09	6·18	6·05
Increase	2·04 or 50 per cent.	2·56 or 71 per cent.	2·30 or 61 per cent.

The increases averaged 61 per cent.

In spite of these large increases in yield, the cost and difficulty of burning even a 1-in. layer of soil preclude its use in general practice. None the less, even if no cheaper method of firing is discovered, the results are valuable for the information they provide on crop-development in Gezira soil. Examination of the root-system showed that root-development, both above and below the impermeable layer, was increased by soil-firing, as shown in Fig. 229 (*c*), the fine roots being more plentiful, and the depth of penetration greater, than on unfired soil. But there was no change in the proportion of discoloured roots nor in the degree of fungal invasion. Wilt did not occur in any of the experiments on soil-firing, so the effect of this treatment on wilt incidence was not discovered. Clouston also found a marked effect of firing on the distribution of soil-moisture even down to

[1] That sagacious poet Virgil, who records so much in the *Georgics* of interest to rurally minded people, refers to a process of firing. The following is from T. F. Royd's translation of the *Eclogues and Georgics*, p. 67:

'Often too 'tis good
To burn the stubbles and with crackling flames
Consume the empty stalks: whether from thence
The earth derives a hidden store of strength
And fattening food, or whether 'tis that fire
Bakes out the subtlest vice and sweats away
Excessive damp, or whether by the heat
New pores are opened and the choked are cleared
And so the young blade fed.'—*Editor.*

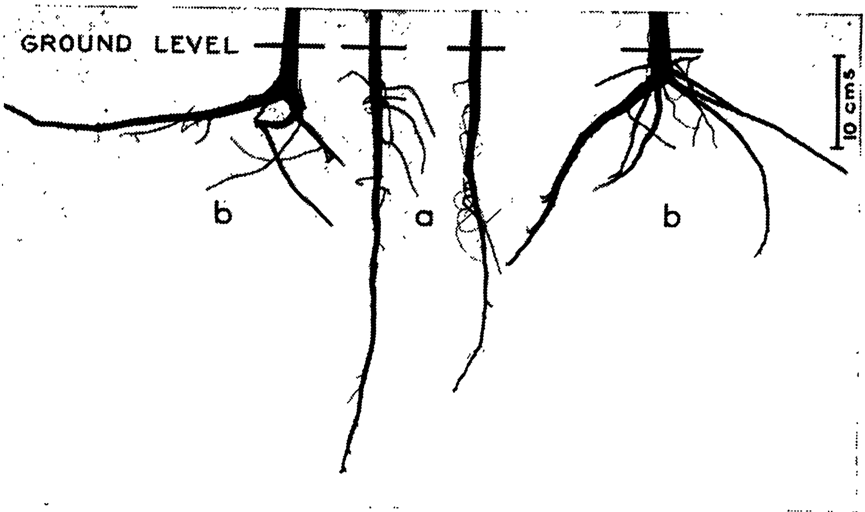


FIG. 232. Cotton tap-roots: (*a*) healthy and (*b*) damaged by termites. The roots were pulled up at the end of the season (Crowther and Barlow, *Emp. J. Exp. Agr.*).

FIG. 233. Firing the surface soil of land to come under cotton by igniting old cotton-sticks (*photo H. W. Barlow*).

a depth of 5 ft. The following result of a comparison of soil-moistures from normal, undisturbed soil and from one where the surface layer had been fired is typical:

	Soil-moisture (percentage of oven-dry weight)		*Gain in moisture in fired soil*
	Normal soil	*Fired soil*	
1st 18-in. depth (surface to 18 in.)	33·0	28·5	−4·5
2nd 18-in. depth (18 in. to 36 in.)	21·1	22·5	+1·4
3rd 18-in. depth (36 in. to 54 in.)	23·8	26·5	+2·7

Firing the surface layer allowed more moisture to penetrate into the lower soil-layers, where the moisture-content increased at the expense of the top layer. Firing also increased the activity of the micro-organisms which fix nitrogen, and since these require abundant oxygen-supply, the result indicates that firing improved soil-aeration—a result in harmony with the freer movement of water.[1]

Clouston at first considered that the benefit arose by the entry of fired soil into the cracks which abound whenever the soil of the Gezira dries out. The fired soil formed permeable veins which enabled water to pass through the impervious layer down into the subsoil, there to sustain the cotton crop late in the season, as described. Laboratory experiments failed to confirm this as the chief value of firing. Instead, the effect appeared to be mainly a surface one, and Clouston concluded that a layer of fired soil protects the crumb structure of the soil below it against the beating-action of heavy rain; for rain, falling on unprotected soil, breaks down the surface structure so that the finest clay particles block the interstices in the top layer of soil, restricting water-movement and aeration and thereby checking root-growth and the fixation of nitrogen by soil micro-organisms. Laboratory experiments supported this interpretation by showing that cotton was stunted if grown in pots which received their moisture from water sprayed on to the surface of the soil to simulate the beating action of rain.

To summarize: the investigation of wilt, unlike those on blackarm and leaf curl, has not led to the discovery of a single causal agent whose elimination saves the crop from damage. Instead, the field has steadily widened and the value of the work accomplished has not been confined to information about the disease. Knowledge has been gained on the rooting-habits of cotton in the Gezira and on soil conditions affecting the development of the crop. With the probable elimination of blackarm and leaf curl, it is likely that future improvement in yields will be wrought increasingly by alteration of soil conditions, and in that field, as well as in the realm of plant pathology, the knowledge gained from this investigation of wilt disease will have lasting value.

[1] Perhaps some of the advantages of soil firing can be obtained by hoeing weeds on resting land. Compare the discussion at pages 482 to 484.—*Editor.*

VI. PLANT BREEDING AND PLANT INTRODUCTION

The most important problem confronting plant-breeders in the Sudan, both before and after the opening of the Sennar Dam in 1925, was the improvement of the cotton crop which has been so vitally important in the economic development of the country. Work on other crops, even on dura, the staple diet of the people, has had to take a subsidiary place because of the demand for more suitable varieties of cotton, especially of Egyptian cotton, a demand which increased in urgency when disease damage grew serious and had to be overcome with the least possible sacrifice in the high quality of the lint. Only since 1935–6 has the progress made with Egyptian cottons allowed much attention to be devoted to other crops.

EGYPTIAN COTTONS (*Gossypium barbadense* Linn.)[1]

The Egyptian long-staple cotton, considered in the world markets as second in quality only to Sea Island, is grown throughout the Gezira Scheme, the Gash Delta, and Tokar. Judged on a cash basis, the crop comprises 90 per cent. of the total Sudan cotton.

When attempts were made early in this century to develop cotton-growing in the Sudan, it was natural that Egypt should be regarded as the source of a regular seed-supply. Since the varieties grew reasonably well, at first no effort was made to improve them. That they grew well was good fortune for the Sudan in view of the differences in climate during the cotton seasons of the two countries, differences arising from both site and sowing-date.

In 1912, when R. E. Massey became the Economic Botanist, plant-breeding was included among his many duties. Working at Shambat, his method was to continue importing new strains of suitable type as they became available and, within the commercial crop of the Sudan, to select individual plants which resembled most closely the original parent. By 'selfing', i.e. ensuring self-fertilization by covering the flowers before they open and thus excluding foreign pollen, he produced nucleus strains of higher purity than the commercial crop, the aim being to avoid the progressive lowering of quality which occurs when one commercial crop provides the seed for the next. Massey also isolated several strains which, under Sudan conditions, appeared superior to the imported types. Unfortunately this work had only transient value, for the varieties grown then, Afifi and Assili, were eliminated in both Egypt and the Sudan by the development of the Sakel variety, which contributed so greatly to the prosperity of both countries during the following 20 years, and is still widely grown in the Sudan.

Sakel was introduced into the Sudan about 1913 and Massey, using both single plants and bulk selections (after the removal of rogues), obtained several improved strains. One, known as Massey's Selected Domains[2] Sakel, came from an importation from Egypt in 1922, and is

[1] The botany of commercial cottons and additional notes on varieties grown in the Sudan are given on pp. 325–328.—*Editor*.

[2] The term 'Domains' used of Sakel strains refers to the State Domains administered by the Ministry of Finance in Egypt. One of the estates, at Sakha, was the home of the purest Sakel seed.

still grown as the standard variety on some of the Gezira permanent experiments. Another, Sakel 186, proved superior to the Gezira commercial crop in repeated trials and was grown throughout the Gezira Research Farm in 1923–4. To improve the quality still further, Massey introduced seed of Sea Island cottons from the West Indies and made selections from the resulting plants.

From his results, Massey concluded that the Sudan could readily be made independent of outside sources for seed-supply. Because of this, and of the greatly increased importance of the crop after the opening of the Sennar Dam, more work was imperative, and in 1925 M. A. Bailey was appointed the first full-time plant-breeder. Like Massey, he decided to make Shambat the centre for plant-breeding work to avoid the mixing of strains between the experimental and commercial crops. To ensure close contact with the Gezira Scheme, A. R. Lambert conducted experiments at the Gezira Research Farm in co-ordination with those at Shambat.

Bailey, inheriting from Massey various strains and continuing similar investigations, found that the Sea Island strains were more vigorous than Sakel vegetatively but suffered from a failure of the bolls to open fully and also from a low ginning out-turn (proportion of lint to seed-cotton). For improved quality he introduced hybrids between Egyptian and Sea Island types, obtained from the Cotton Research Board, Giza. While this work with single plants was in progress he instituted in the field a series of tests, at Shambat and in the Gezira, with the strains already under propagation, and in the 5 years up to 1930, Sakel 186 proved consistently superior to other Sakels, including that of the commercial crop. Unfortunately, after a very promising beginning, much of his work, as well as that of Massey earlier, became of no avail when leaf curl swept through the Gezira and other areas, for thereafter resistance to leaf curl had to take precedence over all other considerations. This meant the entire reorientation of the plant-breeding work.

Strains Resistant to Leaf Curl

The rapid development and spread of leaf curl in the Gezira from 1927–8 have been described in the preceding section. The disease overran the Shambat crop in 1928–9, affecting all the Sakel strains. The derivatives of the hybrids from Sea Island crossed with Sakel appeared especially susceptible to the disease, and this 'rendered necessary the scrapping of much promising material'. Thus, almost all the effort which had been expended came to nothing and it seemed that a fresh start would have to be made.

But in the Gezira Lambert, from his regular observations of the commercial crop, had early seized on the potential seriousness of the disease factor. In 1923–4 he had made selections from a field of Massey's Sakel 186, the variety used that year for the main crop at the Gezira Research Farm, on the basis of power to 'grow away' from blackarm attack. By 1927–8 one of these field selections had given rise to seven families which he passed on to Bailey at Shambat. The next year one of these families

produced the strains later to become famous as X1530[1] and X1730. When leaf curl swept through the crop, this family, originally selected for blackarm resistance, revealed considerable resistance to leaf curl at the Gezira Research Farm. At the same time certain strains, derived by selection from Sea Island, which were susceptible at Shambat, showed 'markedly greater resistance to leaf curl than any of the surrounding strains of Sakel' when grown at the Gezira Research Farm and at Barakat near by—another example of the way in which varieties appear to change their resistance to disease with changing sites, as previously mentioned in the account of leaf curl (v. p. 549 and p. 554).

By 1930–1 the seed of these leaf-curl resistant varieties was being propagated as rapidly as possible to allow further examination. One strain mentioned at that time has already been described for its susceptibility to wilt disease, XH1229, a hybrid between Sakel and Sea Island. It never reached commercial production for it did not thrive, and in the northern Gezira was especially inferior. Others were the Shambur Sakels, derived from Sea Island, which, though resistant, suffered in yield through incomplete opening of bolls; and Lecrem, selected by Lambert from Massey's Selected Domains Sakel for its resistance to leaf curl. It is in the Annual Report of that year, 1930–1, that X1530 and X1730 are first mentioned by name, the report of the Lancashire graders upon them being as follows:

'X1530 (ex Lambert's B.A.R. Selection) $1\frac{1}{4}''$–$1\frac{5}{16}''$. Medium to strong; brown; rather wanting in lustre and fineness. 7·51d.

'X1730 (ex Lambert's B.A.R. Selection) $1\frac{1}{4}''$. Medium strong; brown; wanting in lustre and fineness. 7·26d.

'July futures on same date 7·26d.'

[1] H. E. King has kindly supplied the following information on the nomenclature of the various cotton strains.

Three systems have been used by the Plant Breeding Section, and are illustrated by the following:

(1) X1530. X = *ex*, out of; 15 = the family number; and 30 = the year of sowing in the breeding plot.
   XH1229. H = hybrids of the Egyptian type, e.g. Sakel × Sea Island; i.e. the 12th hybrid family of the 1929–30 season.
   XA129. A = American type; i.e. a strain from the 1st family of the 1929–30 American Upland pedigree line breeding plot.
   X1530A. A small capital letter following the number indicates an improved substrain of the same general character as the original breeding stock; i.e. X1530A = the first improved substrain of the X1530 stock.

(2) 511, 511A. In this system new strains are given a serial number in a register of seed stocks, and a small capital letter is added for subsequent selections.

(3) N.T.2/33. N.T. = New Type; 2 = the serial number of the strain; 33 = the year of the appearance of the strain, i.e. N.T.2/33 appeared in 1933–4 and N.T.2/39 is the product of six seasons of selection.

The second and third systems were used for both Egyptian and American types.

B.A.R. = Blackarm resistant, e.g. B.A.R. N.T.2/41 denotes the blackarm resistant N.T.2 produced in 1941.

S.P. A Uganda number, i.e. Serere Progeny. B.P. = Bukalasa Progeny.

G.L., G.S. The commercial crop of the Gezira from the X1530 and X1730 types is sold under the symbol G.L., L being the initial of A. R. Lambert who originally selected the strains. G.S. is the selling name for the Gezira crop of Domains Sakel.

The initials 'B.A.R.' refer to Lambert's original aim of selecting for blackarm resistance, but these varieties possessed the power not of resistance in the sense used by R. L. Knight but of recovery after an attack of the disease. Vegetatively they were stocky, upstanding plants, a little later in fruiting than Sakel. The staple length, 1¼ in., was near to that of the commercial crop, but the comments upon lustre and fineness show that the selections were slightly inferior in quality, and this has been confirmed in later reports.

Because of the marked resistance to leaf curl, these and other strains were propagated increasingly and, under the direction of T. Trought, who succeeded Bailey as Chief Plant Breeder, were ready for comparison in small-scale trials by 1932–3. This was a year of very low yield and especially severe leaf curl in the Gezira, a very opportune season in which to test for vigour and resistance. Trials in different parts of the Gezira confirmed the outstanding value of X1530, and the results from the replicated variety trial at Barakat Seed Farm, although not typical, indicated increases in yield from X1530 remarkable in a commercial crop:

Variety	*Yield of seed-cotton in Kantars per feddan*	*Ginning out-turn (lint as per cent. of seed-cotton)*
Gezira main crop (Sakel) .	1·56	27·7
X1530	3·51	30·0
XH1229	1·37	25·7
Shambur IV . . .	1·52	26·6

The yield in seed-cotton of X1530 in this experiment was double that of the commercial variety, and its superiority in lint-yield was even greater because of the improved ginning out-turn. The other strains were not outstanding and were subsequently abandoned, but it was decided to develop the X1530 strain as rapidly as possible for commercial production. Its area that year had been only 15 feddans, but in the next year it was increased to 773 feddans, in regions distributed through the Gezira to provide a further comparison with the commercial crop. In the following year, 1934–5, its area reached 12,000 feddans and it was also widely grown in the Gash and Tokar. In the Gezira its yield exceeded that of Sakel by about 1 kantar per feddan or at least 20 per cent. In 1935–6, when it was grown on 57,240 feddans, it passed from the trial stage and was accepted as a commercial variety for much of the Gezira Scheme—the first variety produced within the country to succeed on a large scale. In recent years either the X1530 or the related X1730 strain has been grown over at least half of the Gezira each year, occupying the southern and central districts. In the north, Sakel, originally imported from Egypt, has persisted, partly because of its higher quality and partly because the superiority in yield of X1530 is not as pronounced there as farther south.

Meanwhile the plant-breeders were required either to improve the quality of X1530 up to that of Sakel or to search again for leaf curl resistance among strains which had maintained or even improved upon the quality of the commercial Sakel crop. Also greater resistance to black-

arm was needed, for blackarm had contributed much to the failure of the crops in 1930–1 and other years. All these requirements have been tackled.

The improvement in quality of X1530 has progressed gradually but is still incomplete. A selection from the original strain led to X1530A, with improved lint and yield, but greater success was achieved with another derivative of Lambert's strains, X1730A, which had completely replaced X1530 in the Gezira by 1939. The yield-performance of these various X1530 and X1730 strains compared against Sakel may be judged from the following data, giving the averages of 18 variety trials made by the Plant Breeding Section, mostly in the central Gezira, during the 8 years 1935–6 to 1942–3.

Strain	*Yield of seed-cotton (kantars per feddan)*
Sakel (commercial crop)	5·25
X1530 and X1730	6·34
Increase	1·09 or 20·8 per cent.

The new strains gave a yield of seed-cotton greater by 20·8 per cent. than that of Sakel. Dealing only with X1730A, the present commercial strain, H. E. King found that in 11 trials during the 5 seasons ending 1938–9, the lint-yield of X1730A had averaged 38 per cent. more than that of Sakel. Nevertheless, though the performance of X1730A in yield is satisfactory, it still requires improvement in quality.

The search for strains of full Sakel quality, possessing at the same time leaf-curl resistance, has chiefly centred round the N.T.2 types. These were derived from a single plant found by J. A. Mann in the commercial Gash Sakel crop in the Gash Delta in 1929–30, and were subsequently selected by Trought, King, and Knight for leaf-curl resistance, lint-quality and yield. An example of the leaf-curl resistance possessed by these N.T.2 strains is given in the following counts of infected plants by F. W. Andrews in a variety trial conducted in the Gash area in 1938–9.

Variety	*No. of plants showing leaf curl*
Domains Sakel	328
N.T.2	31
X1730A	1

The early comparisons of quality were made between N.T.2 strains and commercial Gash Sakel, and the comparison was definitely in favour of N.T.2. But in 1938–9 the Sakel area of the Gezira previously sown with Gash Sakel was sown with a fresh importation of seed from Egypt, now called Domains Sakel (distinct from Massey's Selected Domains Sakel). This Domains Sakel proved to be of superior quality by virtue of the work of the plant-breeders in Egypt, with the result that the N.T.2 did not show the same degree of superiority to the commercial crop as previously. Further work is being conducted by S. H. Evelyn on the purification and improvement of these strains, and meanwhile, since they already possess lint approaching the Sakel strains in quality, with an advantage in leaf-curl resistance and yield their inclusion in the commercial crop is not likely to be long delayed.

Summarizing: in the 10 years since the introduction of X1530 and X1730, the improvement in quality in these strains has been slight, all strains showing a harshness to the touch and a lack of lustre. Attainment of the full Sakel standard from within these strains is not in sight, but is more promising with the newer strains, such as N.T.2, where quality has never been sacrificed to other considerations and the search is confined to resistance to disease and to improvement in yield. As a third line of investigation Evelyn has successfully isolated, from Massey's Selected Domains Sakel, strains resistant to leaf curl, and is now engaged in the selection of strains, both resistant to leaf curl and of improved lint-quality, from the present commercial crop of Domains Sakel.

Strains Resistant to Blackarm

Because the severity of blackarm disease in the Gezira varied from year to year, it never caused the alarm that the sudden spread of leaf curl occasioned. Nevertheless the desirability of resistance to blackarm has always been recognized. Thus Lambert as early as 1923–4 wrote regarding methods of combating blackarm: 'Isolation or breeding of immune or more resistant strains or varieties than the present Sakel (Massey's No. 186) . . . is probably the most promising means of ultimately dealing with the problem.'

At first little progress was made in selection for actual resistance to blackarm, as distinct from the capacity of strains to grow away from the disease. In 1932–3, at Trought's suggestion, T. W. Clouston sprayed a suspension of blackarm bacteria in water (v. Figs. 234 and 235) on to a wide range of Egyptian strains growing in the field in Shambat, but all seemed equally susceptible to the disease. Later, the observation of R. G. Archibald in 1925 that American Upland cottons (*G. hirsutum*) appeared more resistant than Egyptian was confirmed in tests at Shambat, and some American varieties proved especially resistant. This presented the problem: could this resistance of American cottons be transferred to the Egyptian cottons by cross-breeding, without introducing at the same time the undesirable qualities from the American parent which would cause deterioration in the high quality of the Egyptian lint? This problem was tackled by Knight and Clouston from 1934 onwards. The prospects of success were not bright, for work in other parts of the world on the resistance of cotton varieties to blackarm had led to the belief that resistance depended upon a complex of small factors which singly had little or no effect. If this were true, then the transference of the entire complex from one type to the other, without the accompanying adverse factors, appeared an impossible task. Methods of transferring characters, such as flower-colour, plant-colour, lint-length, &c., had been developed by S. C. Harland in his 'backcrossing' technique, but although such methods had been used successfully with other crops, they had not yet produced a commercial strain of cotton. Knight and Clouston adopted his method in their experiments.

Knight has suggested the following simple illustration to outline the technique for the transference of a single factor. Suppose there are two tubes containing liquids, one with red ink representing Egyptian cotton,

FIG. 234. Preparation of spray of blackarm organisms for infecting the crop of experiments on the breeding of blackarm-resistant strains. Infected debris is broken up and soaked in water (*T. W. Clouston*).

FIG. 235. Applying a spray of blackarm organisms. The spray was prepared as in Fig. 234, and is being applied to the experiments on the breeding of blackarm-resistant strains (*T. W. Clouston*).

and the other with water representing American cotton. In the water there is a blue speck, corresponding to the factors of blackarm resistance present in American cotton. The problem is to transfer the blue speck from the water to the red ink without any permanent dilution. Pouring both liquids into the same tube corresponds to crossing, or the fertilizing of one strain by the other; and when the resulting liquid is divided again into the two tubes there are two dilute solutions of red ink of which one contains the blue speck. Using only the liquid containing the blue speck and adding this to fresh red ink, which corresponds to crossing back to the Egyptian parent, and then dividing again into the two tubes, the blue speck is in a less dilute solution and is at the stage of the first backcross. Repeating the process, using each time fresh red ink and the mixture containing the speck, a solution is obtained which gradually becomes practically fresh red ink but contains in addition the blue speck. This represents the new blackarm resistant strain obtained by repeated backcrossing to the Egyptian parent. The rapidity with which American 'blood' is in practice eliminated by this method is illustrated in the following table showing the proportions of American and Egyptian 'blood' in later generations:

	American (percentage)	*Egyptian (percentage)*
Initial cross (F_1) . .	50·0	50·0
Backcross 1st . .	25·0	75·0
„ 3rd . .	6·3	93·7
„ 5th . .	1·6	98·4
„ 7th . .	0·4	99·6
„ 9th . .	0·1	99·9

After 9 successive backcrossings the new strain contains 99·9 per cent. Egyptian 'blood' as well as the factor for resistance.

It was necessary to create a scale of blackarm resistance, so Knight and Clouston, using as a criterion the amount of disease on the leaves, introduced a series of 13 grades, '0' being for varieties completely immune and '12' for those fully susceptible. Three of these grades are illustrated in Fig. 236, which shows typically infected leaves of the American (grade '3') and Egyptian (grade '12') parents, and of a successful backcross (Grade '6'). Later work showed that all commercial Egyptian strains were graded '12', whereas American strains varied from '10' to '3'. Some Asiatic cottons were immune and therefore graded '0'.

The American type selected to supply the quality of resistance was Nye's Uganda B31, graded '3'. At Shambat this variety grew poorly and gave little yield, but all that was required of it was pollen. To ensure that the progeny of this and other unions were adequately exposed to blackarm infection, the plants were sprayed on three successive days with a suspension of the bacteria in water (v. Figs. 234 and 235).

The first cross with B31 was made in 1934–5, with the leaf-curl resistant X1530 type as the Egyptian parent, and the first backcross in 1935–6. Out of a total of 1,156 plants reared from the first backcross, and duly sprayed, 277 proved to be fully susceptible grade '12', and the remaining 879 resistant, the grade varying from '4' up to '8'. The ratio

more than a single quality from the Egyptian parent, might have defeated the purpose of the breeding by fostering undesirable qualities. Since all Egyptian varieties were fully susceptible, no amount of selection in the field could have produced strains resistant to blackarm, for the resistance-factors were not hereditary in the composition of Egyptian cottons. The identification of the few definite factors concerned in blackarm resistance has not only produced commercial strains but has also helped in the systematic classification of the world's varieties of cotton.

The work of adding blackarm resistance cannot be considered complete until at least all three of the factors at present recognized have been added to both the important commercial strains, Domains Sakel and X1730A; and the later backcrosses to Domains Sakel will have to be to a leaf-curl resistant strain when this has been produced, for the present crop is susceptible. Then, and only then, will it be possible to relinquish some of the costly control measures described in the section on diseases.

The breeding work is already branching out, and the addition of blackarm resistance to the commercial varieties of American cotton for the rain areas is described later. A completely new departure is an attempt to do a parallel piece of work by transferring a factor for jassid-resistance from a variety Tanguis (*G. barbadense* L.) of Mexican origin. It would seem that dense hairiness of leaf discourages jassids, and Knight has already transferred a factor, labelled 'H', to Sakel by backcrossing as far as the 8th generation. A difficulty to be overcome is that hairiness of leaf is thought to be closely associated with roughness of lint; unless these can be separated the work may fail. Outside this work on backcrossing King has produced by straight selection a hairy strain of X1530 which Evelyn has purified for hairiness, and this, though attacked by jassids, has shown in 2 years' tests a higher resistance to them than X1730A. In view of the increasing ravages of jassids in the northern Gezira, this breeding of jassid-resistant types, if successful, may prove to be as valuable a contribution to the prosperity of the Sudan as the breeding of strains highly resistant to blackarm.

American Cottons (*Gossypium hirsutum* Linn.)

American cottons are grown both under irrigation in the Northern Province of the Sudan and under rain farther south. The area under irrigation has never been great; and it has been much reduced since, in 1939, the Government schemes abandoned cotton cultivation, leaving Zeidab, owned by the Sudan Plantations Syndicate Ltd., as the only large scheme now growing American cotton. Most of the rain crop is grown in two widely separated areas, namely the Nuba Mountains and Equatoria Province. In these, but for the war, cotton cultivation would now have been on the increase. Considerable expansion may be anticipated after the war.

Massey, especially during 1922–5, worked on American as well as on Egyptian types, and Bailey inherited both types when he took over the work in 1925. The Americans comprised strains obtained by field selection from the commercial crop on the pump-schemes, and numerous introductions, mostly from America. Although no American cottons were

grown commercially at or near Shambat, the breeding work was centred there until 1936–7, largely because it could be carried on simultaneously with the work on Egyptian cottons. Bailey's method was to select promising single plants found anywhere between Shendi and Uganda, propagate at Shambat for seed, and then conduct trials with the most successful in both the northern and the southern Sudan.

The only strain surviving from Massey's early work is Pump Scheme. Its origin is somewhat obscure but it was imported by Massey, and its original composition appears to have been a mixture of Nyasaland Upland, Sunflower, and Allen. It succeeded under irrigation and was for many years the commercial crop in the Northern Province. It was also introduced into the Nuba Mountains rain area at the beginning of cotton cultivation in 1923, there to remain the principal commercial variety until the present time. A possible factor in its success is its mixed nature, for it is still composed not of plants of a single strain but of a mixture of strains. Possibly some of the component strains thrive in one set of conditions, some in another, with the result that it grows vigorously in widely differing circumstances.

Though the lint of Pump Scheme was classed as 'long-staple', and therefore 'good quality', American cotton, it suffered by a lack of purity deriving from its mixed nature, and much effort has been expended in improvement by isolation from it of the most suitable pure strains. Yet in replicated trials during many years, none proved a sufficient advance on Pump Scheme, by the combined merits of quality, yield, and ginning out-turn, to warrant a change in the commercial crop; and in 1932–3 Trought stated that it had proved difficult to obtain a cotton consistently to outclass Pump Scheme strain. Later work with these and other selections is reviewed under localities, since a strain which succeeded in one area rarely proved as successful elsewhere.

Northern Province

Several of Massey's strains derived from single plant selections were grown on an area of 300 feddans in Mikeilab in 1925–6. Later Bailey selected a single plant, known as XA1129, from the Meade variety which Massey had introduced from the U.S.A. This was considerably better than Pump Scheme in lint quality, and under irrigation gave an earlier crop and a much higher ginning out-turn. Experiments showed an increased cash return from it of 20 per cent. over Pump Scheme, and eventually it was widely grown, especially in the Dongola district, where it continued to be the principal variety so long as cotton was grown there. Like many American cottons it was resistant to leaf curl, and this disease did not interfere with the breeding programme of the American cottons in 1928–9 and the following season as it did with Egyptian cotton.

Farther south, in the Berber district, the crop regularly suffered severe loss from pink bollworm (*Platyedra gossypiella* Saund.) and a variety which matured earlier than Pump Scheme was essential. For these conditions Trought produced from his own Punjab Early strain, grown in India, one labelled '513', and this, although of shorter staple and lower quality than Pump Scheme, soon became popular, yielding double the amount of those

strains which were ravaged by pink bollworm. By 1936, 513 was the commercial variety of the district, and together with XA1129 ousted Pump Scheme from the irrigated areas. It should be noted that at Zeidab the Sudan Plantations Syndicate Ltd. continues to grow a direct importation of its own, Wild's No. 11, which at present produces the best quality of all American cottons grown in the Sudan but does not give high yields.

Nuba Mountains

Although Pump Scheme was replaced in the areas for which it was originally selected, it has held its own much longer in the Nuba Mountains. XA1129 was tried but did not succeed in replacing Pump Scheme. Numerous strains were introduced from Uganda, but none proved suitable without further selection. In 1935 the Nuba Mountains became the centre of the breeding work on American cotton, and R. R. Anson, who was then appointed to work full time on American cottons, took over the strains which had been developed by Bailey and King at Shambat, transferring them to Kadugli. Now there is a choice of several which are superior to the commercial crop in the cash return to the cultivator.

One, N.T.58/39, originating from an outcross found in a family of 513 grown at Talodi, has been under constant selection since 1937, because by its higher ginning out-turn it yields more lint than Pump Scheme, and the lint, being stronger, is of better quality; and, moreover, it matures earlier. Another, N.T.205/41, which Anson obtained by selection from S.P.20, an importation from Uganda, matures very early, yields heavily, and possesses resistance to both jassids and blackarm. Knight showed that Pump Scheme, unlike many American cottons, was fully susceptible to blackarm, but that many, though not all, of the plants of the strain N.T.205/41 possessed the B_2 resistance-factor. Anson and Knight have now made it pure for B_2, and this promising material is being increased as rapidly as possible. A third strain, N.T.96/40, was obtained by Anson by selection from a cross made by Evelyn while still working at Trinidad, and introduced to the Sudan through the plant-breeders in Nigeria—an illustration of the way in which the development of new commercial strains is facilitated by the chain of plant-breeders maintained by the Empire Cotton Growing Corporation. This strain matures early and has a specially high ginning out-turn. Finally a fourth, Deltapine, introduced from the Delta and Pineland Co. in the U.S.A., is the most remarkable of all in its exceptionally high ginning out-turn and lint-yield in the Nuba Mountains.

The following table gives the average yields of lint per feddan for N.T.58/39 and Deltapine as compared with Pump Scheme, from 7 experiments conducted over 3 seasons:

	Yield of lint	
	Rotls per feddan	*Percentage of Pump Scheme*
Pump Scheme	245	100
N.T.58/39	263	107
Deltapine	345	141

Although the quality, and therefore the market value, of Deltapine is lower than that of Pump Scheme, because its fibre is harsh, wiry, and slightly coloured, yet, since it gives an increase in lint-yield of 41 per cent., the cultivator still gains far greater cash returns from growing it. Both Deltapine and N.T.58/39 were grown for propagation in 1943–4, so there are now available two strains much superior to Pump Scheme, one in which yield is greatly increased at the cost of some loss in quality, and the other in which improved quality is combined with a slight increase in yield; and a third, N.T.205/41, which matures very early, will follow shortly.

Cotton markets are always uncertain and it may not be desirable to change an established marketable product for one of lower quality, even though the yield is greater, and in the past this consideration has favoured Pump Scheme. But now that such promising new strains are becoming available, in which yield improvement is combined with maintenance of quality, it seems probable that the final elimination of Pump Scheme as a commercial variety in the Sudan is not far distant.

Equatoria Province

The cotton crop in the south of the Sudan is grown in two zones separated by the White Nile. The eastern tract has a smaller rainfall than the western, though both have a long rainy season compared with the Nuba Mountains. At the outbreak of war the area under cotton was about 9,000 feddans in the eastern, and 2,000 feddans in the western, zone. For export the heavy cost of transport to the sea prohibits the growth of all strains but those yielding lint of high quality; but for local spinning quality is less important.[1] Of the strains developed by the plant-breeders one of the first to show promise was XA129, obtained from a single plant selected by King in 1926 from Pump Scheme. In variety trials made over 5 seasons it gave an average increased yield of 22 per cent. over Pump Scheme, and since 1938 has been the main crop in the eastern zone.

Apart from this, most improvement has been wrought with introductions from Uganda, as would be expected since the cultivation in the western zone is merely an extension of the cotton area of northern Uganda. In 1929, Bailey obtained S.G.85 from G. W. Nye, then Senior Botanist in Uganda, and selections from this gave various strains labelled 511. At Maridi, over 3 seasons, one of these gave a lint-yield 35 per cent. greater than that of Pump Scheme, and 511D is now the commercial variety in the western zone. Hence Pump Scheme is no longer grown in Equatoria Province.

Deltapine, which succeeded so well in the Nuba Mountains, gave the lowest yield of all varieties when tested at Maridi in 1942–3. More success has attended an introduction by J. D. Tothill, the strain S.P.84 from Uganda. From 3 years' experiments at Maridi, and also east of the Nile, Anson found that it slightly outyielded the earlier introduction and commercial variety, 511D, and this same superiority of S.P.84 has also been demonstrated at Kagelu, in similar tests made over 2 years in co-operation with H. Ferguson. The new variety, which has the additional merit of

[1] A spinning mill is now being erected in the Zande District as part of Tothill's Zande development scheme.—*Editor.*

earlier maturation, or a selection made from it by Knight for resistance to blackarm, S.P.84 Resistant, bids fair to become the commercial crop during the next few years.

In this extension of his work on blackarm resistance to American varieties, begun in 1940–1, Knight found that, although some of the commercial strains possessed blackarm resistance, the degree varied considerably from plant to plant within the strain. Hence his first task, before embarking on the transference of the factors for resistance, was to spray a blackarm suspension over a plot containing the partially resistant strain to eliminate the susceptible plants in it (Figs. 234 and 235). By using only the seeds from the remainder, and later eliminating plants which did not breed true, maximum benefit was derived from the resistance already present in the strain.

Then Knight proceeded to add the B_1 and B_2 factors from the Uganda strain B31, used to supply resistance to the Egyptian strains, only to find that with few exceptions, wherever the factor B_1 entered into the composition of a purely American strain, a proportion of markedly dwarfed plants, which never grew taller than 8 in., were produced. Since these plants were low-yielding, it was obviously undesirable to transfer the B_1 factor, and later work has been concerned with only the B_2 and B_3 factors.

In 1942–3 Knight, working in Equatoria Province to ensure that the resistance of the various strains was measured under typical field-conditions, found Pump Scheme, XA129, and Deltapine all to be more or less fully susceptible and to require the addition of the factors B_2 and B_3. The four strains 511D, N.T.58/39, N.T.205/41, and S.P.84 Resistant, however, already contain B_2 and need only the addition of B_3. They show considerable resistance in Equatoria Province and the value under the new conditions of this B_3 factor, which has so far only been added successfully to Egyptian varieties, is at present conjectural.

To summarize: new strains are now available for the Nuba Mountains and Equatoria Province which represent advances in both quality and yield; and their performance in the field will be enhanced by the increased resistance to blackarm disease now being developed in them.

DURA (*Sorghum vulgare* Pers.)

Dura introductions and selections were another of Massey's many tasks; and later Bailey, Lambert, King, and Knight, in what time they could spare from cotton, attempted to improve the crop; but the first to be appointed specifically as 'dura expert', in 1928, was A. W. Punter. Bailey had begun a systematic collection of dura varieties from all parts of the Sudan, and Punter, taking this over, grew more than 150 distinct types at the Gezira Research Farm in 1930–1. He began also a series of variety trials comparing various strains of Feterita both in the irrigated and in the rain areas of the Blue Nile Province, but the work was given up in 1931 through the economic depression and was not resumed on any considerable scale until 1939, when Evelyn took it over.

The dura sown in the irrigated area of the Gezira has always been mostly of the Feterita variety, but the seed is mixed, and, as with 'lubia' but in contrast to cotton, no specially selected seed is issued for sowing. Massey

introduced strains of Feterita from America and one of these, No. 1931, had some success; but with no regular scheme for a reissue of the seed it has not been preserved commercially as a distinct type. Punter, in selections from the rain areas, chose one, Dwarf Feterita Manāgil, for its exceptionally early maturation—it took only 40 days from sowing to flowering and another 40 to harvest. He found in the Manāgil district local cultivators adept at seed selection. They chose heads from shoots with the fewest leaves, having observed that those ripened first.

Evelyn has compared various Feteritas in numerous variety trials in the Gezira and on the White Nile pump schemes, together with two of the best introductions from the U.S.A., Dwarf Hegari and Dwarf White Milo. The results of (*a*) 5 experiments in the Gezira and of (*b*) 7 experiments in the White Nile and Abd el Māgid areas, all made in 1942 and 1943, are averaged in the following table of weights of grain and straw:

	Yields							
	Gezira Scheme				*White Nile and Abd el Māgid*			
	Air-dry wts. (rotls per fed.)		*Percentage of Feterita 1931*		*Air-dry wts. (rotls per fed.)*		*Percentage of Feterita 1931*	
Variety	*Grain*	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*
Feterita 1931 .	1,392	5,969	100·0	100·0	2,086	9,753	100·0	100·0
Feterita, Ma'atūk	1,330	6,607	93·6	110·4	2,284	10,299	109·3	105·6
Feterita Abd el Māgid	1,469	5,297	105·4	88·8	2,106	8,383	101·1	86·0
Dwarf Feterita, Manāgil	1,599	3,708	115·0	62·1	..	..	..	..
Dwarf Hegari .	1,603	4,228	115·2	70·9	1,744	8,642	83·6	88·6
Dwarf White Milo	1,774	5,249	127·5	88·0	2,332	8,671	111·7	89·0

The Feteritas, other than 1931, are named according to the village in the Blue Nile Province from which the seed was originally selected.

In the trials of irrigated dura in the Gezira Scheme, of the Feterita types the Dwarf Manāgil strain produced most grain, but it was handicapped by its small production of straw—only 62 per cent. of the 1931 type. Compared with the Feteritas, the performance of Dwarf White Milo was outstanding, the grain-weight being 27·5 per cent. above that of Feterita 1931, the strain previously considered the best for the Gezira. Being a dwarf type the yield of straw was less, by 12 per cent., but that was small compared with the increase in grain. On the White Nile Feterita Ma'atūk succeeded better than in the Gezira and yielded most grain and straw of all the Feteritas; but Dwarf White Milo, although it gave the highest yield in grain, did not show the same remarkable superiority there as in the Gezira Scheme.

Dwarf White Milo was originally introduced from America by Massey, and in 1930 Punter commented favourably upon it. 'Early White Milo was easily the most promising variety of the American introductions. It was very quick maturing . . . it is a non-tillering type and ripens all at once. The quality of its grain is quite good.' It was included in variety trials and, when Evelyn took over the dura work in 1939, he quickly realized

its value. Besides producing the heaviest grain-yield of all, Dwarf Milo has the additional advantage of immunity to the Gezira strain of common smut disease (*Sphacelotheca sorghi* (Link.) Clint.) which each year destroys some of the Feterita crop unless the seed is treated before sowing with copper carbonate or a similar disinfectant. Further, it is less attractive to birds; in variety trials heads of Feterita are frequently destroyed by birds whereas Dwarf Milo alongside almost escapes damage. Though its hard grain is not as easy to thresh as that of the Feteritas, it appears to be more resistant to storage pests. Independent tests by the native community on its use for 'kisra', their bread, put Dwarf White Milo in a higher class than Feterita, and for 'marīsa', their beer, it is equally good. Thus there is now available for distribution a new dura whose apparent merits make it the first variety seriously to rival Feterita as the best for the Gezira irrigated tract.

Evelyn has increased the collection of strains of dura up to 352, and many of these are being purified and propagated for further trial and for cross-breeding. When a new strain is introduced into any district the dietetic aspect must not be overlooked, for dura flour constitutes a very large proportion of the diet of the people. Evelyn and O. W. Snow have therefore started a systematic study of the nitrogen-content of the grain of the different strains to ensure that no strains lower in nitrogen than the local variety are recommended. The work has shown that there is no apparent relation between seed-colour and nitrogen-percentage, but strains with heavy individual grains appear to contain a higher nitrogen percentage than those with smaller grains.

The uncertainty and localization of rainfall have handicapped the work on rain varieties in the Blue Nile Province, but useful data are being collected. Elsewhere the work is still at a preliminary stage. In the Nuba Mountains several varieties have been tested for a number of years with some success, among them Kau and Kurgi, which are late-maturing types resistant to damage by birds and locusts. Evelyn started systematic observations in 1940–1, when a large number of varieties were tested at Dilling, a site chosen for its accessibility by road throughout the dura season, and at Talodi. Many have given consistently good yields over the three years of observation in unreplicated trials, and were included in variety trials in 1943–4 to decide which should be propagated for distribution to the cultivators.

In Equatoria Province A. G. McCall, in conjunction with Evelyn, has carried out variety trials at Maridi for 4 years with local, Kordofan, and Gezira types. When the rains are light the highest yields are from such varieties as Dwarf Hegari, originally introduced into the Sudan as early maturing types for the Gezira, but in years of heavy rainfall the local ones succeed best, for the northern types have compact heads which easily become mouldy in wet years. Comparing at Kagelu a series of early maturing duras recently introduced from Uganda, Ferguson found that, unlike the northern duras, they both pollinated and matured in wet conditions. It is, however, too early yet to recommend any one dura for distribution in Equatoria Province; and this conclusion applies also to the Northern Province Tokar and the Gash Delta, where similar work is in progress.

OTHER CROPS

Since dura had the first claim on any time which remained to the plant breeders after their work on cotton, selection of improved strains of other established crops and introduction of new crops have been only on a relatively small scale. In preliminary work at Shambat Massey, from 1920, and later Bailey and King, made numerous introductions and conducted trials with wheat, sesame, dukhn (*Pennisetum typhoideum* (Burm) Stapf and Hubbard), castor oil, and various beans, but the development of this work in the different districts of the Sudan has been largely the concern of the Inspectors of Agriculture, helped by the Research Staff when time has allowed.

The Gezira Scheme

Here cotton has been the principal crop since the first pump scheme was started in 1911 at Taiyiba, and while the cotton continues to yield well and hold its own in the world's markets, the prosperity of the Scheme is assured. But should it fail there is as yet no other cash crop to succeed it. All alternatives, tried on a small scale, have so far failed. Wheat is grown successfully as a war measure but would not be profitable in peace-time. That the prosperity of the Gezira, and with it the entire Sudan, should be dependent upon the continued success of a single crop is a situation which cannot be viewed with equanimity.

With a successful cash crop of cotton and a food crop of irrigated dura, the need has been for improved fodder. 'Lubia' (*Dolichos lablab* Linn.) is an old-established crop in the Sudan in river-bank cultivation, and it has always been included in the irrigation schemes of the Gezira and White Nile. Yet numerous trials at the Gezira Research Farm for more than 25 years have produced no strain of 'lubia' good enough to replace the main unselected crop as originally grown at the start of the Scheme, and no other legume better than 'lubia' of the genus *Dolichos*.

Lucerne (*Medicago sativa* Linn.; Arabic: 'bersīm hegāzi') grows well when sown in winter, but, being perennial, it is barred on the commercial area through the absence of irrigation from April to July. Pigeon pea (*Cajanus cajan* (L.) Millsp.) is not relished by the inhabitants in their diet and appears to have, at the best, small beneficial residual effects on the following cotton crop. It is only grown occasionally, as a screen along the banks of water channels. In the past most legumes introduced for trial succumbed either to blister beetle (*Epicauta aethiops* Latr.) when sown during the rains, or to thrips at other seasons; and they were liable to be destroyed by termites at any stage. Termites furnish one reason for the lack of success with ground-nuts at the Gezira Research Farm; in the northern Gezira, where they are fewer and the soil is lighter, ground-nuts are being grown instead of 'lubia' by a few cultivators.

Northern Province

In the north, because the winters are cooler and the soil lighter than that of the Gezira, the range of cropping is wider. Wheat varieties from Egypt and elsewhere, introduced by the Plant Breeding Section, have met

with some success, and much of the commercial crop in the Berber area consisted until recently of selections of Rustom developed by Bailey from his importations from Iraq. Later these were largely replaced by Hindi 62, brought from Egypt. Sakatoon maize (v. p. 319) and field peas have also been introduced.

A noticeable improvement has been made with the vegetable 'bamia' or okra (*Hibiscus esculentus* Linn.). Knight, by selection from the local type, has produced a new strain, known as 'Momtaza', which yields well, is of good flavour, and is easy to gather because its pods are smooth instead of spiny; but it has not yet found favour generally with the Sudanese cultivators who so far prefer the slimier texture of the local variety. Two replicated variety tests at Shambat in 1941–2 gave the following yields:

	Yields of green pods (rotls per feddan)	
	May-sown	*August-sown*
Original local type .	72	2,238
Momtaza . . .	1,631	5,720

The new strain, when May sown, gave a moderate yield whereas the local type failed; and, when sown during the rains, it yielded more than double the local type. Knight selected for resistance to leaf curl disease as well as for other qualities, and Momtaza, like many of the new cotton strains, possesses a fair measure of resistance (v. also p. 362).

Nuba Mountains

There is great scope for improvement in this region, for the number of different crops is greater than in the irrigated areas, and each crop awaits selection and improvement: to date merely the fringe of the subject has been touched. As in other parts of Africa, care has to be taken that varieties are not distributed which do well only in years of plentiful rainfall and absence of pests; it is desirable, even if their yield in a good year is somewhat inferior, that they should be able to withstand locust-damage and drought, and thus avert famine.

Two strains of dukhn from Nigeria known as 'brown' and 'black' have proved successful against bird- and locust-damage, presumably through their awns which protect the grain. These have yielded considerably more than the local types. Wheat has been tried, but unsuccessfully. Sesame has given indications that Nigerian strains may be improvements on those already grown.

Of the legumes, soya beans have been tried unavailingly, but at least one new strain of ground-nuts appears superior to the types grown locally and may justify distribution later. The following are yields obtained by W. A. Porter and E. S. Colman at Talodi, averaged over 3 years:

	Yield of unshelled nuts in rotls per feddan
Local strain .	934
Barberton .	1,101
Increase .	167 or 18 per cent.

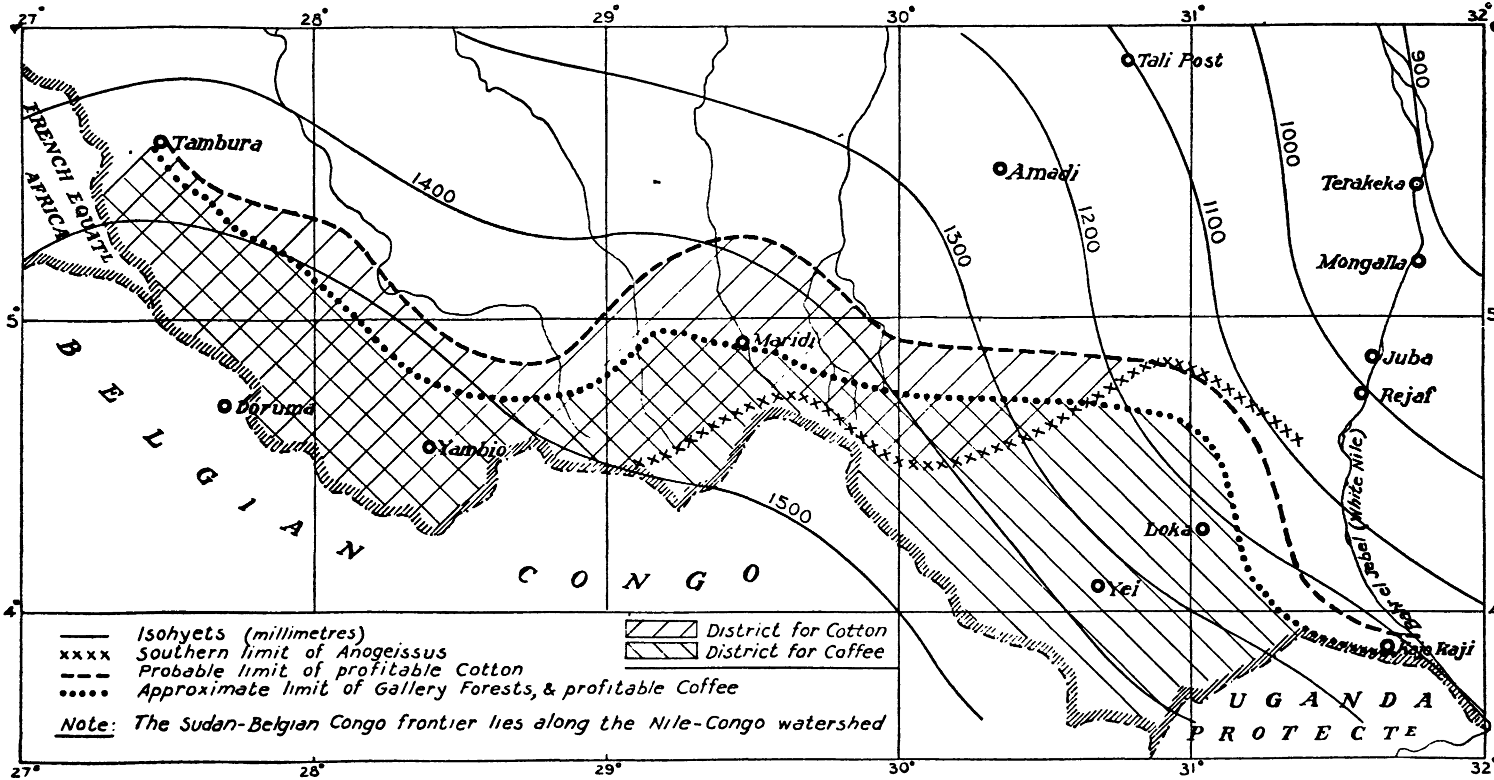


FIG. 237. Map of south-western Equatoria Province showing the area covered by Myers's first ecological survey and the districts he considered suitable for growing coffee and cotton. J. G. Myers's Report.

This result indicates a substantial improvement and is an encouragement to further trials with more numerous introductions.

Equatoria Province

Here a promising beginning in organized plant introduction was made by T. Cartwright, who was stationed at the Kagelu Farm for many years from about 1916. In addition to the achievements of the Inspectors of Agriculture who worked for a considerable period under the guidance of G. F. March, much success has attended the enthusiasm for new crops of individual administrative officers, such as Major Logan Gray at Kagelu and Major J. W. G. Wyld at Yambio.

The first systematic approach was made in 1937 when, to enable the Director of Agriculture and Forests to advise on developing the province and introducing suitable crops, J. G. Myers made a preliminary study of parts of Equatoria Province, and this will be described later. When Myers's death in 1942 interrupted the work, H. Ferguson continued the plant introductions and the recommendations of Myers are being followed up.

Although cotton is envisaged as the main cash crop and some export of oil-seeds is likely, initial efforts are being directed towards raising the standard of nutrition, especially towards the elimination of famine in those districts liable to suffer it, and the production and consumption of pulses in regions where cattle are excluded because of the tsetse fly. A strain of ground-nuts introduced from farther north, Kordofan Central African, has outyielded the local types at Maridi and seed of it has been propagated and distributed to the cultivators. Of the beans most commonly grown, namely strains of cowpea (*Vigna unguiculata* Walp.), a wide range has been compared at Kagelu. Trials with soya beans started by R. S. Sullivan at Maridi have been more successful than in the Nuba Mountains. The highest yields have been from G.R.F.14 (derived from Poona Black) but, this strain is disliked for its black seed-coat, and hence for distribution G.R.F.10 (derived from Sind 10, *ex* Mirjohnhat) is being propagated.

The work on cereals is complicated by the cultivators' custom of mixed cropping as an insurance against pests and extreme variation in weather. A mixture, not only of varieties but even of crops, is deliberately sown together, that variety or crop best suited to prevailing conditions growing at the expense of the others. Dura and 'telebun' (*Eleusine coracana* Gaert.) are grown mixed together and also eleusine and sesame mixtures. Experiments on such at Maridi have already been described on p. 491. Before specific recommendations can be made about individual varieties of crops for this purpose, much work is needed on the practice of mixed cropping itself.

Strains of upland rice, introduced from the Belgian Congo, have been grown successfully by McCall at Maridi. From the local cassava A. P. Milne has made selections for resistance to the mosaic disease general on the native crop. This disease is illustrated in Figs. 238 and 239 comparing healthy and diseased leaves and plants. Several resistant types, introduced from Kenya and West Africa, are being studied at Kagelu and Maridi, and the early indications are that yields are higher from the resistant than from the susceptible types. A yam (*Dioscorea alata* Linn. type) introduced to

FIG. 238

FIG. 239

Mosaic disease of cassava in Equatoria Province showing healthy and diseased plants (Fig. 238) and leaves (Fig. 239) (*photos Bloss*).

Kagelu from Ceylon gave the remarkably high yield of 21 tons per feddan, and, if the growers are willing to do the necessary cultivation, it promises to become a valuable food-crop.

Trials with sugar-cane made by Ferguson have shown that several varieties grow satisfactorily at Kagelu and on the flood plain of the Nile at Juba. Most trials have been made with the P.O.J.27/25 variety introduced by Tothill from Uganda; the best time of planting is July–August. Except for sustaining damage by termites, the crop is a healthy one. It grows most successfully on land where the natural vegetation is guinea grass (*Panicum maximum* Jacq.) or elephant grass (*Pennisetum purpureum* Shum.), and, since preliminary experiments indicate that cotton grows well on similar land, cotton may prove to be a suitable crop to rotate with sugar-cane.

Much of Equatoria Province is suited to tobacco cultivation, but the development of this crop is not encouraged at present. Of the fibre plants other than cotton, Ferguson has selected a local strain of jute (*Corchorus olitorius* Linn.), which, in the latest trials, has produced fibre of quality and yield comparable to the Indian crop; it is suitable for further trial along the banks of the Nile and around Maridi.

Small trials have been made on a large variety of crops, and a collection of about 300 varieties of field crops, nearly all from Equatoria Province, was grown at Kagelu in 1943. A wide range of varieties of plantation crops also has been examined and among the successful introductions are tung oil, derris, and numerous fruit-trees. Tea, although a failure at Kagelu, has grown fairly well in the higher, wetter area to the south. Cinchona and cacao, introduced by Cartwright, did not succeed.

An Ecological[1] Survey of Equatoria Province

As a first step towards the economic development of the southern Sudan and the social emergence of its people, it was decided to initiate an ecological survey. By reason of its remoteness the area must remain to a great extent self-supporting and its exports to the world's markets must be confined to those high-priced commodities which can absorb the great cost of transport. The survey was designed to explore both avenues of development, and Myers, appointed in 1937 to work under Bailey's general direction, was asked to make a botanical survey of the province of Mongalla, which, with a soil survey by H. Greene and O. W. Snow, would provide the foundations for a systematic policy of plant introduction and trial. Later the work was extended by adding an ethnological survey, and by including the Bahr el Ghazal Province when it was amalgamated with Mongalla to form Equatoria Province.[2]

Myers, up to 1942 when he met his untimely death in a road accident while at work on his survey, made good progress in the area around Yei, Maridi, and Yambio, and the following account is based on his reports. No reference is made to his work farther north since it was not completed.

[1] Ecology—that aspect of biology which concerns the relation between organisms and their surroundings.

[2] This vast area is proving difficult to administer as a single Province and subdivision is again under consideration.—*Editor.*

Even the small part of the province around Yei, Maridi, and Yambio is a region 360 miles long and an average of 35 miles wide, the width varying between 10 and 80 miles. An investigator travelling by car along the roads would see little of the natural, unaltered vegetation, probably only scrappy vestiges on waste ground between cultivated plots; for sleeping sickness regulations have in the past required that the entire population should live along the roads, which themselves often run on high ground not representative of the whole. The only satisfactory procedure was therefore to walk, and Myers made extensive foot traverses over the area.

The accompanying map (Fig. 237) shows the region to abut on the international boundary of the Sudan with Uganda, the Belgian Congo, and French Equatorial Africa. Its altitude is nowhere below 2,000 ft., and rises to 3,900 ft. in the Aloma Plateau south of Yei. The general slope is downwards from south to north, but there is a secondary slope from west to east. The region is well watered and well drained, and there are no swamps of any size. Between the rivers the country is generally undulating. The underlying rocks, predominantly gneisses and granites sometimes overlain by ironstone, and the soils have already been described in earlier chapters by J. D. Tothill (at p. 140), H. Greene (at pages 153 to 156), and G. Andrew (p. 120). The rainfall, as shown by the isohyets on the map, ranges from 1,400 to 1,500 mm. (56 to 60 in.) in the west, but is less east of Yei, that of Kajo Kaji being 1,200 mm. The length of the dry season increases towards the north-east, and Myers believed that this factor alone would limit the success of coffee cultivation there. The rainfall varies considerably from year to year, and these variations affect the yields of cotton. Soil erosion so far has not been great because cultivated plots are small and there is no 'clean cultivation'. But with the roads running along ridges and the population largely confined to the roads, there is great risk of both over-cropping and increased erosion in the future.

In his botanical survey Myers recorded that in the first 6 months he had collected specimens of 2,000 plants, of which 300 of the most common were identified on the spot, and another 600 were sent to Kew for determination. The distribution of the vegetation has been described in the chapter on vegetation (v. pages 46 et seq.), and it is sufficient to state here that, apart from local forests, the whole area falls into the ecological unit of 'high grass-woodland', with vegetation defined as grasses from 6 to 10 ft. tall and trees varying from 'patchily closed canopy' to 'open orchard bush' or even fewer trees. An important factor in the maintenance of this type of vegetation is fire, which sweeps the region every dry season.

No attempt is made here to describe the survey in detail, but three characteristic trees which Myers utilized must be mentioned. The tall conspicuous *Lophira alata* Banks is practically confined to the poor and least altered ironstone, and therefore where it predominates no success can be expected with crops like cotton, coffee, and oil palm. The tree *Isoberlinia doka* Craib and Stapf is an indication of medium growth of grass mixed with woodland, and it was the southern limit of this tree that Myers used to fix the line on the map indicating the probable northern limit of successful cotton cultivation. *Anogeissus schimperi* Hochst

abounds over the area but stops short towards the south, apparently where the elevation reaches 2,500 ft., and this break, also marked on the map, appears to indicate the limit of successful cotton cultivation in the south.

The local forests are of two types, 'gallery' and 'depression'. 'Gallery' forests are regarded as outliers of the West African rain-forest; they occur in conditions of lower rainfall than in West Africa, as tongues of varying width along the margins of the larger streams, sustained by the more abundant ground-water. They are invaluable both as conservers of excess rain-water and as preventers of erosion, and Myers considered that they should be strictly protected. He indicated their northern limit and suggested that it defined also the limit of successful coffee cultivation. The 'depression' forests (v. fig. 11 on p. 51) are supported by the run-off of surplus water from the surrounding smooth rocky hills, and probably the largest one is the Azza forest, whose undergrowth is much damaged annually in harvesting wild coffee. Grasses are encroaching on this forest as a result of fires.

Because of the annual grass fires and the shifting population, gradual deterioration is in progress everywhere, the original valuable heavy woodland changing to less useful scrubbier types. Myers pressed the need for legislation to protect the vegetation and create sanctuaries of natural vegetation and game, for research in improved crop rotation, and for education to disseminate the information and experience gained.

Agricultural development requires not only suitable land but also suitable cultivators; and, fortunately, the western half of the area is peopled by Azande, who are pre-eminently agricultural and amenable to administration. They have few domestic animals, but produce very diversified crops, many with numerous varieties. Unlike the cultivators farther east, who are of mixed tribal origin, they have little use for money. Unfortunately the population is sparse and if anything on the decrease, and this, if combined with any restriction regarding living near the roads, must limit the area coming under crops.[1]

Diet is almost exclusively vegetarian largely because of the ravages of the tsetse fly; even where stock are kept, they are rarely eaten. The animal contribution to the diet is supplied mainly by termites, and their oil is used for cooking; otherwise meat is obtained only by hunting. Myers, because of the 'all prevailing and ever present longing for meat', stressed the necessity for modifying the Dinka cattle-industry farther north to produce dried meat for sale in this area. This production of meat has made good progress since the report, and may stimulate in the Azande a desire for money. Meat is desirable on dietetic grounds to increase resistance to disease, for the Azande, with the least animal protein in their diet, are the most susceptible to leprosy. Myers urged that the survey should be extended to include investigation of the native diet before great changes are introduced.

In his survey of the crops Myers reported that in one morning in a single Azande settlement he collected 68 crops, all named and definitely

[1] The restrictions about living near roads have now largely been removed.—*Editor.*

distinguished, including such rarities as, for example, a sedge, *Cyperus articulatus* Linn., cultivated for its scented rhizomes. All require evaluation, for some could probably be introduced with advantage to the tribes farther north who, with no such variety, suffer periodic food shortage. That new crops have been handed on is evidenced by the wide distribution in Equatoria Province of cassava, maize, sweet potato, and ground-nuts, all originally non-African plants.

In this immense range of crops high yield is not the only criterion of suitability or success. Political considerations intrude; sugar-cane and tobacco, which grow well, are both subject to restrictions.[1] The high cost of transport and fluctuations in market prices both interfere. Tsetse fly, by preventing the keeping of cattle, upsets the balance of the diet and thus affects the health and vigour of the cultivators; and control measures against sleeping sickness restrict the area which can be cultivated.

The main cereal crop is 'telebun', *Eleusine coracana* Gaertn. Dietetically, it is preferable to dura and it keeps better, but it is very susceptible to locust attack. Formerly it was exported, but recently production has been sufficient only for local needs. Two crops of maize a year are grown and a third should be possible in the wettest areas; and it stores well in the cob. Myers advocated trials with various American and other strains, and these are now in progress. In the Yei district dura is grown for food, farther west mainly for 'marīsa' (beer); as an export crop it cannot compete with that of the northern Sudan because of the heavy transport costs. Dukhn succeeds in the driest area around Kajo Kaji. Upland rice is grown on the high land south of Yei, and in the Zande district it is occasionally interplanted among coffee, and Myers suggested that wetland types should be tried in the latter area, where, in any case, the marshy districts have to be cleared for control of sleeping sickness. Recently Ferguson has had considerable success with wetland types in terraced swamp-land at Kagelu.

A favourite food-crop is cassava, and the bitter type produces a greater weight of food per feddan than any other crop commonly grown by the natives. It provides an insurance against famine, since it is not eaten by locusts and involves no storage problems, for it can remain in the ground in good condition until required, even up to 4 years. Myers introduced an improved method, that of the South American Indians, of preparing cassava flour, whereby fresh bread can be eaten the same morning as the roots are dug, instead of after 4 days as with the local method. Except for the mosaic disease (v. Figs. 238 and 239) it is a remarkably healthy crop, and Myers considered that both the flour and the tapioca should be earmarked as possible export crops for the future. At his suggestion, work on selection and distribution of mosaic-free plants is in progress.

Ground-nuts, so important in the diet because of their protein content, can produce two crops a year. Myers suggested that they might be intercropped with coffee and cotton; and in this Milne, in experiments conducted subsequently, has had some success. Sesame which, besides providing oil and crushed seed for flavouring cereal food, is in Yei the

[1] Sugar-cane is now being grown to supply a jaggery factory to be installed as part of the Zande Scheme.—*Editor.*

next money-crop to coffee, but its development for export depends on the erection of mills for crushing and improvement of the low yields.

Oil palms, distributed from the Kagelu Experimental Farm and from the District Commissioner, Yambio, were readily accepted since they were grown across the Congo border. Myers showed the cultivators a new method of extracting the oil, which has a high content of Vitamin A, and the crop is being extended for local consumption, though its possibilities for export are not promising. Many essential oils and medicinal plants are grown successfully. One, *Hydnocarpus wightiana* Blume, produces an oil very effective in the treatment of leprosy, and sufficient should be grown in the province for local requirements.

In the Azza forest Myers found three distinct species of wild coffee. Both *C. robusta* Lindon[1] and *C. arabica* Linn. are under investigation at Kagelu, and he considered that much of the area surveyed is suitable for the cultivation of *robusta*, the probable northern limit being indicated on the map. The success of *arabica* is as yet uncertain, for, as compared with other areas where it is grown, the elevation is insufficient, the soil too acid, and the plants tend to over-bear and die back. A nice adjustment of shade for the coffee plants is necessary, but *Albizzia zygia* C. J. F. Maclr., which was favoured earlier, is now thought to have too many surface roots. All the coffees are unusually free of disease and pest-damage, except for the fungus *Hemileia* on *arabica*, and should the price be satisfactory—at present it is depressed by the Egyptian consumption tax—the success of the industry is likely, especially in the Yei district.

The most immediately practicable money-crop is cotton. Myers estimated that it could be grown profitably in the area shown on the map, that is, from about 10 miles beyond the limit of the gallery forests to as far south as the 2,500-ft. contour; but its development to date has not been easy. Several ginneries built in 1928 were closed by 1931, and with the removal of Government pressure on the cultivators to grow the crop, the area has decreased considerably; and the crop persists only among the Azande and tribes related to them in the Maridi area. Reasons for its lack of appeal are that it needs clean cultivation, which is irksome, and that the picking coincides with the peak of the all-important season of hunting and the gathering of honey. Unlike coffee, cotton is attacked by numerous pests and diseases, especially the insect *Helopeltis*. Myers stressed that no crop requiring clean-weeding should be encouraged until adequate measures against erosion have been taken, for extensive areas of bare soil should be 'anathema to agriculturists in the wet tropics'. In early attempts to develop the crop the cotton was grown for several successive years in large communal plots, for ease of supervision. Instead, Myers, with Milne, advocated that it should be grown in small plots of a half to one feddan, in rotation with other crops. In this way serious erosion would be avoided and a method of cultivation adopted which varied very little from the practice familiar to the inhabitants. This practice has now been successfully introduced.

The second crop of the cotton area is chillies (*Capsicum annuum* Linn.),

[1] By some botanists *Coffea robusta* Lindon is regarded as a variety of *C. canephora* Pierre.—*Editor.*

but the market is small and, if production were much increased, the price would fall below the profitable level. An added disadvantage is the difficulty of storage in the humid atmosphere of Juba. Sisal grows well, but the development of the industry necessitates the building of factories.

A full description of the crops of the province has been given in another chapter. Here it has been possible only to indicate some of the lines of development which are being pursued as the outcome of Myers's survey of a part of the province which, though small, holds out prospects of prosperity. For money crops the Yei district benefits by proximity to the Nile and the resultant lower costs of transport. Eleusine, sesame, surplus dura, and to a less extent, cassava flour, 'lubia', and rice can all find a sale. Yei was the centre of a small coffee industry which, granted a reasonable price, could spread over much of the area to the west. In the Yei district and farther west cotton has met with little success because, being grown for export, transport costs have reduced the price payable to the growers to an unattractive figure.

Myers's conclusion was that, even if export crops should increase but slowly, 'there would seem no insuperable obstacle to the building up of an economy within the province, independent of world prices, by which the agricultural tribes and the pastoral peoples, developing and extending on their own lines, could exchange their complementary products to the benefit of both'.

Myers did not live to see his dreams come true; but in 1944 Tothill, whose experience in Fiji and Uganda gave him a special interest in the problems of the southern Sudan, submitted a plan for the economic development of the Yei to Yambio area and for the educational and social emergence of the people concerned. This plan, which centres round the growing of cotton for use at a spinning mill to be erected in the Yambio district and which contemplates the commercial production of cotton cloth, soap, and jaggery for sale within the Sudan, has since been approved by the Government. Tothill states that it could never have been put forward but for the early work so enthusiastically and intelligently done by Myers. The south, he says, owes to Myers a great debt of gratitude.

Chapter XXI

IRRIGATION IN THE SUDAN

By W. N. ALLAN, M.C., 4N, B.SC. (ENG.), M.INST.C.E., *Director of Sudan Irrigation Department, and* R. J. SMITH, M.A., B.A., *Assistant Director (Development), Sudan Irrigation Department*

The wise man of Miletus [Thales] thus declared
The first of things is water.

J. S. BLACKIE, *The Wise Men of Greece: Pythagoras.*

I. General

IRRIGATION is required for agriculture wherever the rainfall is deficient during the whole or part of the period of growth of the crops to be cultivated. From this point of view the Sudan may be divided into three regions, though the boundaries between these are not sharply defined, and in general the rainfall increases fairly uniformly from north to south.

In the northern Sudan, from the Egyptian boundary to about the latitude of Shendi, the mean annual rainfall, less than 100 mm., is so deficient and irregular that it must be disregarded in any reliable scheme of agriculture. In this area regular crops can only be secured on lands which are irrigated or are naturally flooded by the rivers.

The second region, embracing most of the central Sudan, lies roughly between the 100 mm. and 500 mm. isohyets, the latter being approximately on the line Singa–Renk–Abu Zabbad–Nyala.[1] Here, in years of average to good rainfall, rain crops can be grown in the northern portion of the area only on a limited scale, but farther south with a fair degree of certainty, though still with wide variations in annual extent and yield, depending on the incidence of the rainfall. But since the rainy season is short, the crops so grown are limited to various varieties of millet and other quick maturing types. Crops with a period of growth extending into or through the winter months such as long-staple cotton, legumes, and wheat, and of course all fruit and garden crops, can only be grown on irrigated lands.

In the third region, farther south, the mean annual rainfall ranges from 500 to over 1,200 mm., and generally speaking, this suffices for all cultivation, though from time to time a season of comparative drought seriously affects the crop areas and yields. Here irrigation is only needed on a small scale, for garden and fruit crops during the dry season from December to April.

Irrigation in the Sudan may be classified as follows, according to the method used and the source of supply:

(*a*) Systematic irrigation by free flow throughout, from the river. The only example of this system is the Gezira Scheme.
(*b*) Systematic irrigation, fed by pumps from the river.
(*c*) Flush irrigation—in the delta of the river Gash by inundation canals, and in the delta of the river Baraka at Tokar by natural flooding.

[1] See maps on pages 69 and 34. The central Sudan usually means the 'Acacia desert scrub' and the 'Acacia short grass scrub' vegetation zones.—*Editor.*

(*d*) Basin irrigation—in the Shendi and Dongola districts of the Northern Province.

(*e*) 'Sāqiya' and 'shadūf' irrigation—mainly on the Nile and its tributaries, but to a limited extent from wells.

All these types of irrigation, except the flush irrigation on the Gash and Baraka, and the small area watered from wells, depend for their supplies of water on the Nile and its tributaries. The entire water-supply of Egypt for irrigation and for domestic or industrial use also comes directly or indirectly from the same source. Complete knowledge and control of the Nile water is therefore of the greatest importance to both countries, and the arrangements for storage and distribution have to provide for their varying demands at different seasons of the year.

II. The Nile and its Waters

River Discharges and Storage

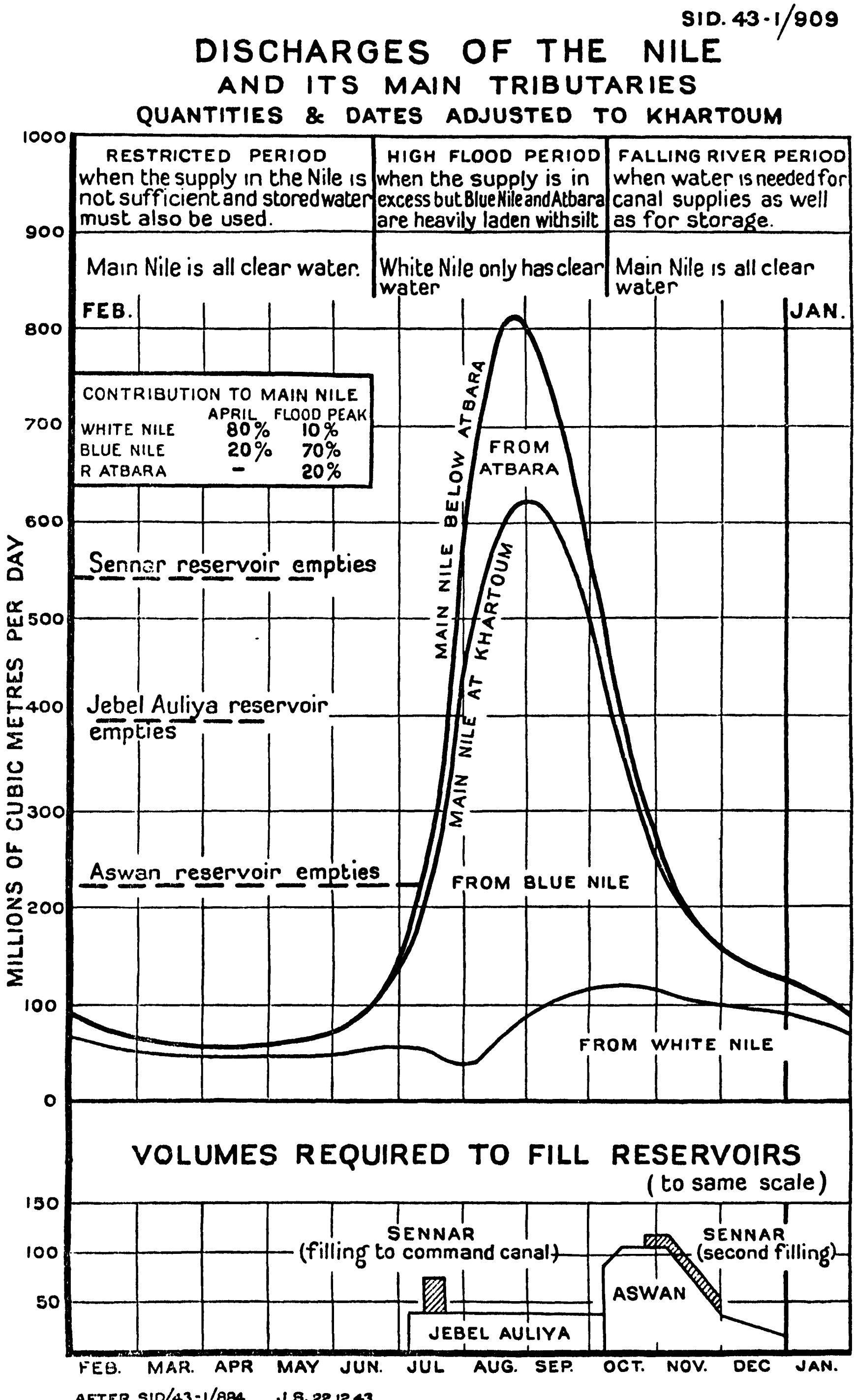
Fig. 240 shows the natural discharges of the river and its main tributaries throughout an average year, and should be studied in conjunction with the following descriptions and figures.

In the low season, from January to June, the mean total discharge of the main river below Khartoum is some 13·8 milliards of $m.^3$ (1 milliard = 1,000 million $m.^3$), of which the White Nile contributes 10 milliards and the Blue Nile 3·8 milliards.[1] The Atbara is dry for practically the whole of this period. Since the last decade of the nineteenth century summer irrigation in Egypt has required the whole flow of the river from about the beginning of March until the rise of the flood, the outlets to the sea being closed annually by earth dams. Since 1902 the natural flow of the river at this season has been supplemented by water from storage reservoirs, which have been provided as follows:

Reservoir	*Date*	*Capacity (milliards of $m.^3$)*	*Remarks*
For Egypt			
Aswan—original . .	1902	1·00	To level 106·0 metres.
,, 1st raising .	1912	2·40	To level 113·0 metres.
,, 2nd ,, .	1933	4·80	To level 121·0 as held at present.
,, ,, ,, .	..	5·20	To level 122·0 max. possible.
Jebel Aulia . . .	1937	3·50	To level 377·2 first reached in 1943.
For the Sudan			
Sennar . . .	1925	0·78	To level 420·7 metres.

From the beginning of July the main river rises rapidly until the peak of the flood is reached about the end of August, when the mean flow is some 15 times the minimum in April. Once the peak is past, the fall is almost as fast as the previous rise until the end of October, after which it is more gradual. From July to December the mean total discharge is

[1] $m.^3$ means metres cubed.



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DISCHARGES OF THE NILE
AND ITS MAIN TRIBUTARIES
QUANTITIES & DATES ADJUSTED TO KHARTOUM
RESTRICTED PERIOD
when the supply in the Nile is not sufficient and stored water must also be used.
HIGH FLOOD PERIOD
when the supply is in excess but Blue Nile and Atbara are heavily laden with silt
FALLING RIVER PERIOD
when water is needed for canal supplies as well as for storage.
Main Nile is all clear water.
White Nile only has clear water
Main Nile is all clear water
CONTRIBUTION TO MAIN NILE
APRIL FLOOD PEAK
WHITE NILE 80% 10%
BLUE NILE 20% 70%
R ATBARA - 20%
Sennar reservoir empties
Jebel Auliya reservoir empties
Aswan reservoir empties
MAIN NILE BELOW ATBARA
MAIN NILE AT KHARTOUM
FROM ATBARA
FROM BLUE NILE
FROM WHITE NILE
MILLIONS OF CUBIC METRES PER DAY
1000
900
800
700
600
500
400
300
200
100
0
FEB.
JAN.
VOLUMES REQUIRED TO FILL RESERVOIRS
(to same scale)
150
100
50
SENNAR
(filling to command canal)
SENNAR
(second filling)
ASWAN
JEBEL AULIYA
FEB. MAR. APR MAY JUN. JUL AUG. SEP. OCT. NOV. DEC JAN.
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FIG. 240.

76 milliards, of which 16 milliards come from the White Nile, 48 milliards come from the Blue Nile, and 12 milliards from the Atbara.

Considering the year as a whole, it will be seen that, broadly speaking, the flood comes from the Blue Nile and the Atbara, while the White Nile contributes the greater part of the discharge in the low-river season.

The waters of the Blue and Main Niles, and of the Atbara, are heavily silt laden in July, August, and September, and the filling of reservoirs on them in this season would result in large annual silt deposits. Therefore the filling of Aswan and Sennar Reservoirs is not begun until October, when the flood has fallen considerably and the silt charge in the water is greatly reduced. The waters of the White Nile are practically silt-free, and Jebel Aulia Reservoir is filled between July and early October.

The Nile Waters Agreement

The distribution of Nile Waters between the Sudan and Egypt is governed by the Nile Waters Agreement of 1929 (Treaty Series No. 17 of 1929), supplemented by detailed Working Arrangements. Summarized, the effect of the provisions of these is as follows:

(*a*) The natural flow of the river and its tributaries is reserved for the benefit of Egypt from 19 January to 15 July (Sennar dates) subject to certain pump irrigation rights in the Sudan set out in (*e*) below.

(*b*) The Sudan may fill the Sennar Reservoir to the level required to give full discharge into the Gezira canal in a period of 10 days beginning on 15 July, or a later date such that the combined discharges at Roseires and Malakal (with a 10-day lag for Malakal) have averaged not less than 160 million $m.^3$ per day for the preceding 5 days.

(*c*) The Sudan may complete the filling of Sennar Reservoir to its full storage level during the period 27 October to 30 November inclusive.

(*d*) The Sudan may take water into the Gezira canal from the river at rates not exceeding the following:

Dates	*Remarks*
19 to 30 July.	On a graduated scale increasing to a maximum of 168 $m.^3$ per second or 14·52 million $m.^3$ per day. The total intake in the period is limited to 101·6 million $m.^3$.
31 July to 30 November.	168 $m.^3$ per second, or 14·52 million $m.^3$ per day.
1 to 31 December.	160 $m.^3$ per second, or 13·82 million $m.^3$ per day. (Subject to certain deductions in very low years.)
1 to 15 January.	80 $m.^3$ per second or 6·91 million $m.^3$ per day.
16 to 18 January.	52 $m.^3$ per second or 4·49 million $m.^3$ per day.

Any water required in excess of the agreed maxima from 1 to 18 January, and all water required from 19 January to 15 July, must be provided from that stored in Sennar reservoir.

(*e*) The Sudan may take water from the river and its tributaries for pump irrigation as follows:

Dates	*Remarks*
From 15 July to 31 December.	Without limitation.
From 1 January to 28 February.	For 38,500 feddans.
From 1 March to 15 July.	For 22,500 feddans.

In respect of any additional areas watered in any month from 1 January to 15 July, compensation water must be released from that stored in Sennar Reservoir, at the rate of 800 m.³ per feddan per month.

Though not specifically mentioned in the Nile Waters Agreement, the principle has been established that the abstraction of water by 'sāqiya' and 'shadūf' shall not be subject to restrictions.

The operation of the Nile Waters Agreement in the 'restricted period', from 1 January to 15 July, is controlled by means of the 'Water Account'. The initial credit to the Sudan in this account is the gross contents of Sennar Reservoir on 1 January, 781 million m.³, plus the abstractions to which the Sudan is entitled from 1 to 18 January (including allowance for evaporation losses from the reservoir in that period) in all 141 million m.³, making a total credit of 922 million m.³. Against the account are debited:

(1) Evaporation losses from the reservoir.
(2) Water taken into the Gezira canal.
(3) Water pumped into the Gezira canal system to maintain a supply of drinking-water during the period May to July when there is no irrigation.
(4) Compensation water in respect of additional pump areas. (See (*e*) above.)

In this account the total volume debited must not under any circumstances exceed the initial credit. The reservoir is completely emptied each year, before 1 June. Thus any unused balance of the original credit is passed down the river at the end of each season.

The method allows considerable flexibility in the operation of the reservoir and is very satisfactory in practice. To illustrate the use made of the total credit of 922 million m.³, the actual figures for 1944 are given:

	Millions of m.³
Reservoir evaporation losses—Jan. to July and minor debits	135
Gezira canal consumption for irrigation—Jan. to April	578
Gezira—domestic supply, May to July	15
Compensation water for pump irrigation, &c.	49
	777
Balance at credit, released to river	145
Total	922

Jebel Aulia Agreement

In 1932 an agreement was reached between the Sudan and Egypt, under which the Jebel Aulia Reservoir has been constructed and operated to give additional water-supplies to Egypt. From the dam, 29 miles from Khartoum up the White Nile, the full reservoir ponds back the river nearly to Jebelein, some 200 miles to the south. The gross contents of the reservoir are about 3·5 milliard m.³, but after allowing for evaporation and losses on the way it is estimated that only about 2·0 milliard m.³ are available at Aswan. The effects of this reservoir on cultivation in the

Sudan, and the solution of the problems arising from these, are discussed in Chapter XXVII (Blue Nile Province).

Future Development

Considering the Nile basin as a whole, the greater part of the water stored in all the reservoirs on the Nile and its tributaries, as well as the natural flow of the river from January until the rise of the flood, is either already used for irrigation or earmarked for developments of the near future. Further increases in systematic irrigation therefore must await the provision of more water at this season. Proposals for this purpose, which have been under investigation for a number of years, are:

(i) A storage reservoir in Lake Tana, at the head-waters of the Blue Nile in Ethiopia.

(ii) A channel through or past the 'sudd' region of the Upper White Nile, to pass down some at least of the water now lost in these swamps. For full effectiveness this work would have to be accompanied by the conversion of Lake Albert into a storage reservoir, to even out the present variations in discharge between high and low years.

These schemes are still in the project stage, though the plans have been investigated in some detail. Water from Lake Tana would be shared between Egypt and the Sudan, while that from the Upper Nile schemes, like that from Jebel Aulia, would be primarily for irrigation in Egypt.

III. Sennar Dam and the Gezira Scheme

The Gezira

The name 'El Gezira', that is, 'the island',[1] was originally applied to all the country between the Blue and White Niles, without any defined limit to the south. For practical purposes now it includes only the triangle lying north of the Sennar–Kosti railway, a gross area of some 5 million feddans. It may be described as a vast plain with a few isolated rocky hills near its southern boundary, but, like many plains, it is by no means uniform in level, though the slopes for the most part are so gentle as to be hardly visible. A block of relatively high land stretches northwards from the Sennar–Kosti railway to a point near Manāgil, from which town it takes its name of the Manāgil Ridge. Another main ridge, less prominent but more persistent, extends from near Wad el Haddad to beyond Masid, roughly parallel with the general line of the Blue Nile, and about 3 to 15 kilometres from it. From these higher lands secondary ridges slope westwards and north-westwards towards the White Nile (Fig. 241).

This topography is related to the characteristics of the two rivers. The Blue Nile comes from a mountainous catchment and flows at a relatively steep slope (1/10,000). The seasonal variation of its discharge ranges from, say, 9,000 $m.^3$ at the peak of a high flood to 60 $m.^3$ in April in a very low year. The corresponding range in level is 10·0 metres, and its channel is a steep-sided trough from 300 to 500 metres wide. The White Nile, drawing its supply from the 'sudd' region and the Sobat, has a slope of about 1/60,000. Its extreme range is in discharge from 1,900

[1] Also used for the word 'peninsula'.—*Editor.*

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GENERAL MAP OF THE GEZIRA

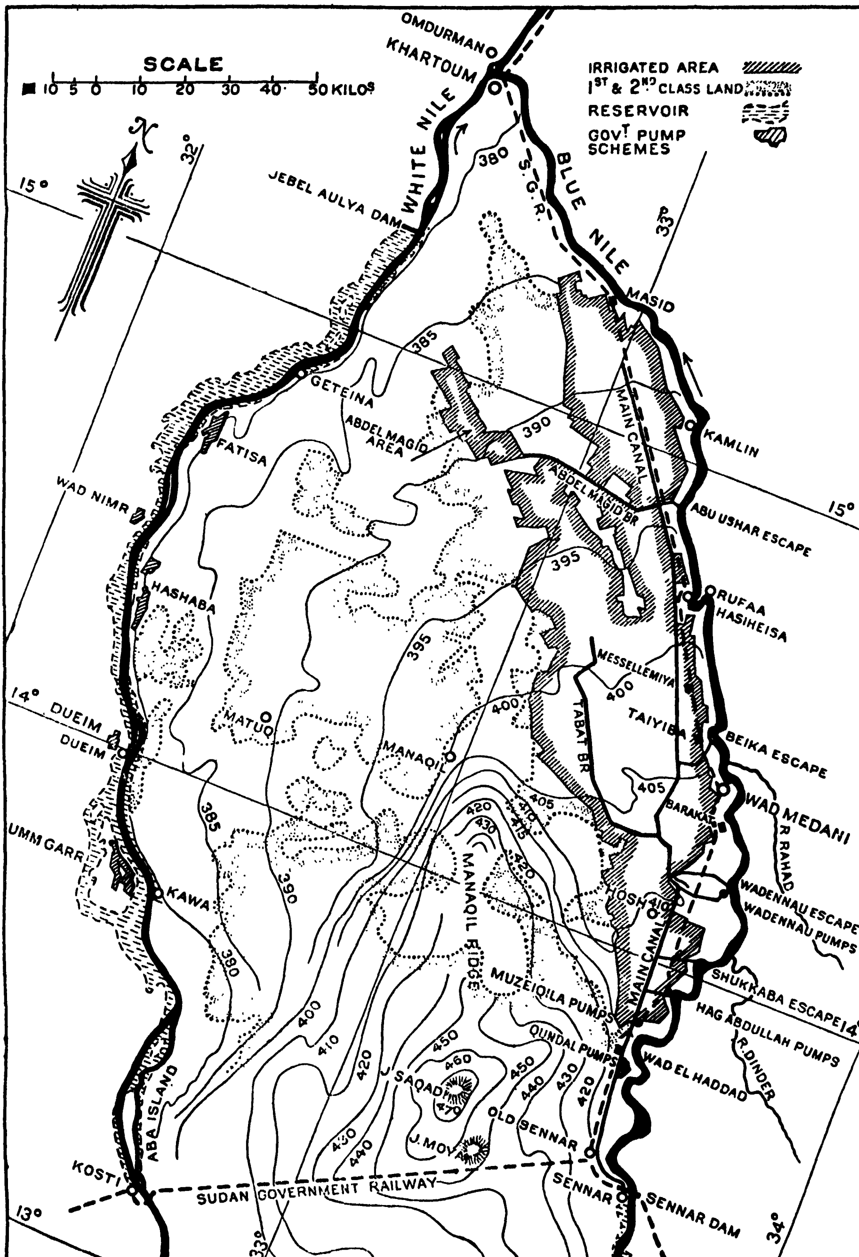

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FIG. 241.

$m.^3$ to 330 $m.^3$, and in level 4·0 metres only. It flows in a wide channel with gently sloping sides.

The surface soil of the Gezira, with its high clay content, has the merit from an irrigation point of view that it is very impervious to water in its undisturbed condition, and thus seepage and percolation losses from canals are low. But it contracts when dry, and expands again when wetted, and for this reason does not provide very good foundations for irrigation structures and buildings.

Rainfall, for practical purposes, is limited to the months June to September. The incidence decreases rapidly from south and east to north and west, as shown by the following mean annual totals:

		mm.[1]
Blue Nile:	Sennar	453
	Wad Medani	400
	Rufaa	320
	Kamlīn	242
Centre:	Manāgil	364
White Nile:	Kosti	401
	Ed Dueim	316
	El Geteina	204
Apex:	Khartoum	159

(*Nile Basin*, Hurst and Phillips, vol. vi.)

The totals of individual years may vary from 30 per cent. below to 50 per cent. above these means. The local incidence of storms is very irregular. Single falls of 120 to 150 mm. in 24 hours are not uncommon in the southern and central Gezira, and 190 mm. in one day has been recorded near Medina, 20 kilometres west of Wad Medani.[2]

Historical. Various travellers in the Sudan in the nineteenth century suggested the irrigation of the Gezira plain, but full investigation and the preparation of definite schemes date from 1904, when Sir William Garstin, of the Public Works Ministry of Egypt, published his comprehensive *Report on the Basin of the Upper Nile.* The factors to be considered were (*a*) land, (*b*) water available, (*c*) the crops to be grown, and (*d*) population.

Land of suitable slope and apparently good quality was in abundance. As for water, even at that date the whole of the natural flow of the river was used by Egypt from early in the year until the rise of the flood, and it was clear that either the crops to be grown on the Gezira must require no irrigation from the beginning of March onwards, or else storage must be provided. As regards crops, cotton, the most valuable, was then and is now grown in Egypt from March to November and requires water throughout the season of shortage. To provide summer water for growing cotton in the Sudan Sir William Garstin originally proposed that the Lake Tana Reservoir should be constructed; if this could not be done, he proposed to grow only wheat and other winter crops, using a barrage or weir across the Blue Nile for the purpose merely of raising the water to a level sufficient to command the head of his main canal. Population was fairly dense in the east-central Gezira, and was thought to be sufficient for a scheme of considerable extent, though it was recognized that this factor might limit subsequent extensions.

[1] 1 inch=25·4 millimetres. [2] Pronounced 'Wod Meddany'.—*Editor.*

The construction of Lake Tana Reservoir at that period was not found possible. Working on the alternative proposal, Mr. C. E. Dupuis, Inspector-General of Irrigation in the Sudan, in 1908 submitted a project for a barrage near Sennar, to hold up the water-level some 7·8 m. only, i.e. to about mean flood-level, and for a canal system to irrigate some 500,000 feddans[1] gross, north and west of Medani, on which the main crop would be wheat.

By this time it had become apparent that long-staple cotton in the central Sudan grew best as a flood-time and winter crop, sown about July, and watered until March or early April, and by 1913 an experimental pump scheme at Taiyiba near Wad Medani had proved the suitability of the central Gezira lands for this crop. A complete project for a gross area of 500,000 feddans was prepared, including a dam at Makwar, now called Sennar, to store some 800 million m.^{3}; cotton was to be the principal crop, though millet, wheat, sesame, and legumes were also to be grown. This project was considered somewhat ambitious, and it was decided to reduce the first instalment to 100,000 feddans, the dam to be built in the first place only to a sufficient height to command the main canal, without providing storage. On these modified lines the project was approved in 1914.

In 1913 there had occurred the lowest Nile flood in the last 200 years; only three other floods as low have occurred in the 960 years for which flood records have been kept in Egypt. The Blue Nile discharges in the early part of 1914 were correspondingly low, and after further study it was realized that in such years Egypt might require all the natural flow of the river at Aswan as early as 18 February, corresponding to 18 January at Sennar. Construction was held up during the war years of 1914–18, but a second experimental pump scheme at Barakat came under irrigation from 1914. By 1918 the whole project had been reconsidered in the light of the additional data which had been collected, and it was decided to build the dam to full height from the start, in order to provide storage to meet the whole of the requirements of the Sudan after 18 January. To provide additional revenue to meet the interest on the resulting increased capital expenditure the area of the first instalment was increased to 300,000 feddans. The final project was prepared in 1918 on lines which would allow of its subsequent extension to 1,000,000 feddans.

The building of the dam and the canalization of the 300,000 feddans area was carried on during the years 1919–25. To give experience to supervising staff and cultivators, and to provide additional data on the water required, two areas were canalized in advance of the completion of the whole scheme, and watered by large pump stations on the river, at Hag Abdullah (1921), commanding 21,000 feddans, and Wad en Nau (1923), commanding 30,000 feddans. After the main canal came into operation in 1925 these pumps were available for lifting the relatively small amounts of water required for domestic supply in the summer, when the main canal is no longer commanded by the reservoir level. In 1925 a gross area of 240,000 feddans was brought under command, including the above areas. The full 300,000 feddans was completed by 1926. On account of high costs in the post-war period the expenditure

[1] Feddan = 1·038 acres = 0·420 hectare.

had considerably exceeded the estimates, and since the agricultural and financial results on the first instalment were satisfactory, a policy of extension was pursued in subsequent years. By 1931 the gross area was 667,000 feddans, and by 1938, 852,000 feddans. Later smaller extensions raised the total by 1944 to 876,000 feddans. It must, however, be noted, in considering these figures, that in the cropping of the scheme a large proportion of the area is rested. This is discussed in more detail in a later paragraph, and also in Chapters XX and XXVII.

FIG. 242. The Sennar Dam under construction in 1924, seen from the west bank. The foundations have been laid right across the river but are under water in the foreground (shallow channel) which is being closed off by a rubble bank. The piles used to close off the deep channel can be seen both above and below the dam, which has been completed well above water-level (*photo E. Mackinnon*).

Sennar Dam and Reservoir

Sennar Dam (Fig. 243) has a total length of 3,025 metres, made up of two lengths of masonry corewall dam, backed by earthen banks, 835 metres long on the east flank and 583 metres long on the west, and of a central length, 1,607 metres long, of masonry dam built of granite rubble. Across the river channel the dam is pierced by 80 sluices, 8·4 metres high by 2·0 metres wide, fitted with heavy steel gates. Above and between these sluiceways, and also on the flanks, spillway openings are formed in the upper part of the dam. These are closed off, when water is to be stored, by timber baulks. At the western end of the masonry dam are the head regulator gates which admit water to the main canal.

The normal seasonal programme of operation of the dam and reservoir begins in July, with the reservoir empty and the river flowing freely through the sluiceways. From 15 July the sluice gates are adjusted daily so that the reservoir level is raised by 25 July to the height required to give full discharge into the main canal. This level is the same as that of the crest of the spillway openings, and through the flood the reservoir is

kept at this level, the gates being adjusted as required to pass the varying flood discharge of the river. The spillways provide additional passageway for water, in case a very high flood cannot be passed by the sluices even at their maximum opening. At this level the reservoir pond is almost entirely confined to the actual trough of the river channel.

By 27 October the flood has fallen considerably from its peak and the silt content of the water is relatively small. The spillways are closed off, and the sluiceways are then gradually closed down so as to raise the reser-

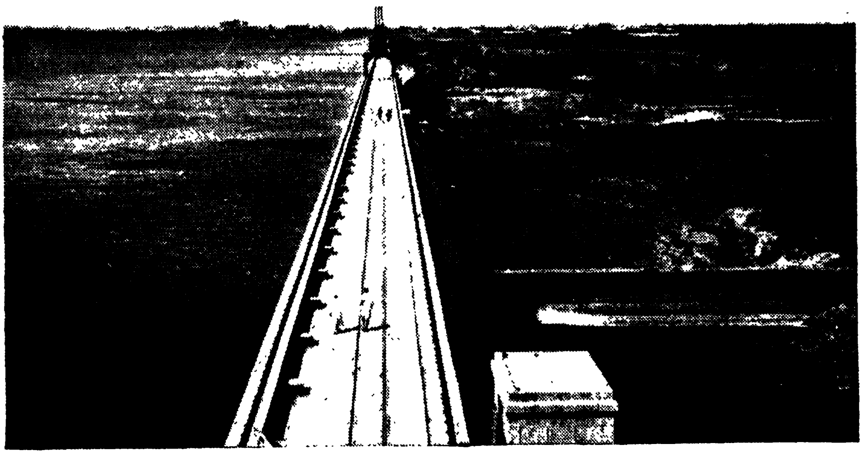

FIG. 243. The completed dam, looking towards the west bank, with water at storage level. River discharge through sluices not visible, but water discharged through spillways can be seen (*photo E. Mackinnon*).

voir to its full storage level by 1 December. The total quantity thus stored is 781 million m.^{3}, of which 448 million m.^{3} is above the level required to give maximum discharge into the main canal, 178 million m.^{3} is below that level, but above the level required for a very small discharge into the canal, and 155 million m.^{3} is below the latter level.

The reservoir is usually kept at full level till 1 February. The level is then gradually lowered, on a programme designed to ensure that full irrigation demands can be met till 10 April, if required, and that a small discharge can be given until 30 April. Thereafter the remaining contents of the reservoir are released to the river, and it is empty by 31 May.

Canalization. The canal system includes the following:

(*a*) The main canal and branch canals—of a total length of 323 kilometres.
(*b*) Major distributaries, a total length of 643 kilometres.
(*c*) Minor distributaries, totalling in all 3,229 kilometres.

The main and branch canals and the major distributaries are carrier channels so alined on the slight ridges and elevated land as to command

the whole area to the best advantage. In them the water flows steadily, day and night, throughout their lengths.

The minor distributaries generally take off from the majors, though a few draw directly from main or branch canals. Their function is to feed directly the watercourses from which the fields are irrigated. One major may feed a considerable number of minors, often both to right and left, but sometimes on one side only, according to the contours of the land. In the greater part of the scheme the length of watercourses has been restricted to about 1,400 metres and the minors are laid out as far as possible parallel at a standard distance apart of 1,420 metres. Minors in most cases irrigate on one side only.

At the head of every channel, from the main canal to the watercourse, is a regulator or sluice to control the supply into it. Control regulators on the main and branch canals and majors are provided at, or near, practically every point of offtake from them, so that the water-level at these points is given a suitable command above that required in the channel taking off. There is thus complete control of the discharge throughout the system, from the head regulator to the minor canal; the regulators are calibrated, so that the water passing each regulator is measured and known.

The minor canals are designed to ensure that the full supply level throughout their lengths is not less than 20 centimetres, and normally not more than 40 centimetres, above the level of the adjacent land, by means of regulators at intervals as required, each consisting of a sluice gate and steel pipe set in an earthen bank across the channel.

The watercourses are laid out at a standard distance apart of 292 metres, which after deducting the width of 12 metres required for the channel itself and an inspection road alongside, leaves 280 metres as the net length of the cultivation plot. With a width of 150 metres, the standard plot is 10 feddans in area, and the standard watercourse of about 1,400 metres feeds nine such plots or 90 feddans in all. The area fed by one watercourse is usually termed a 'number'. Water is admitted into the watercourses through steel pipes 35 centimetres in diameter fitted with a sliding valve on the upstream end; this is termed a field outlet pipe or F.O.P. (see Figs. 244 and 245 showing the detailed layout).

Escapes and Drains. In order to deal with excess water which may result either from heavy rain falling on or entering the main canal, or from heavy reductions in demand following on rainfall on the cultivated area, four large escape channels are provided leading back to the river, at kilometres 57, 77, 108, and 169 on the main canal. These channels have a total length of 37 kilometres.

Heavy rainfall on the cultivable area cannot quickly soak into the impervious clay soil, and tends to accumulate on the lower lands, seriously affecting the young plants if not removed within a short time. In certain areas of the scheme, particularly in the south where the rainfall is heavier, systems of drain channels have been provided so as to draw off the excess from the surface of the land as quickly as possible. These in some cases run out into a depression outside the scheme, or into one of the escapes, but in a number of cases there is no possible outlet for free flow, and pumps are used to lift the water into one or other of the canals. There is

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STANDARD GEZIRA LAYOUT

LAYOUT OF CANALISATION

SCALE 1/50,000

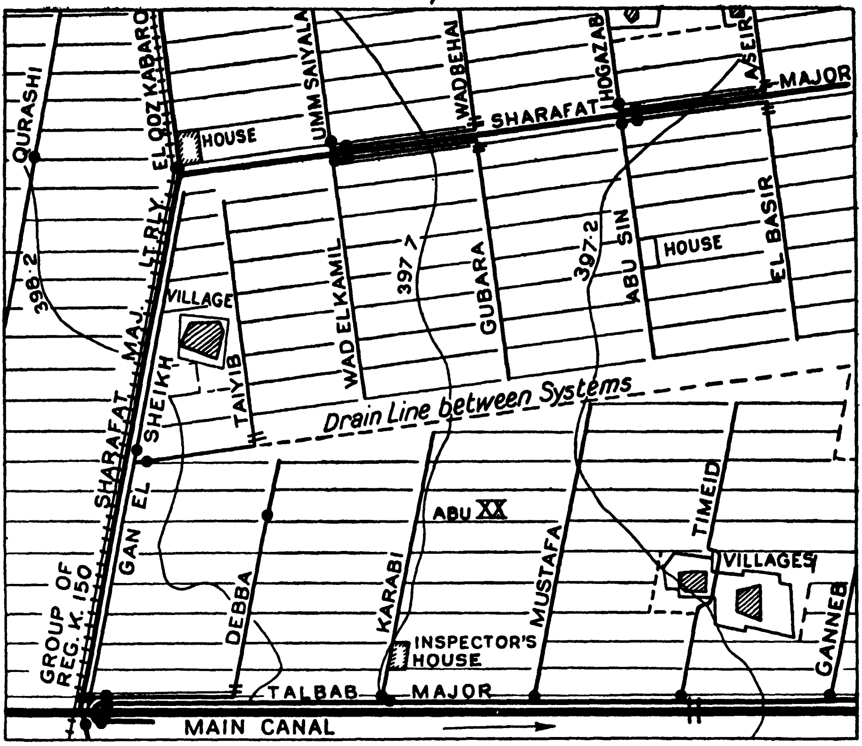

FIG. 244.

SUBSIDIARY CANALISATION LAYOUT

SCALE 1/20,000
(CANALS 1420 M·APART)

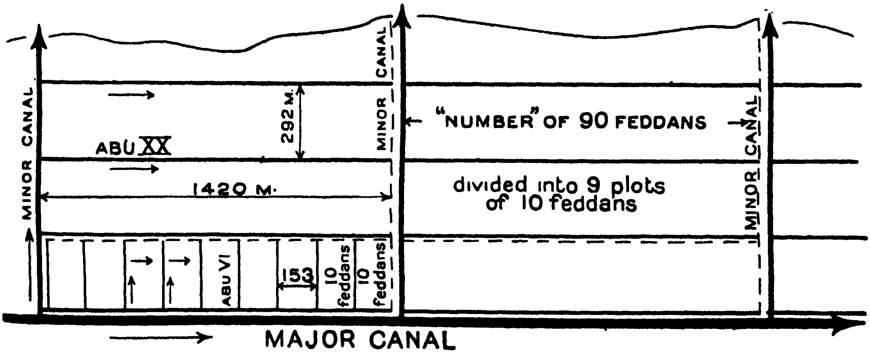

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FIG. 245.

no doubt of the value of these drains, but they are expensive both to construct and to maintain. The total length of drain channels in 1942 was 792 kilometres, ranging from 1·0 to 7·0 metres in bed width.

Cropping and Water Requirements. The water requirements of an irrigation scheme vary at the different seasons of the year, with the climatic conditions, the proportions of the gross area under crops, and the types of crops grown. The cultivator in the Gezira Scheme does not own his land, but holds it on an annual tenancy, as explained elsewhere (v. p. 191). This allows of uniform schemes of cropping throughout, a feature of the scheme which is probably almost unique. This control was instituted for agricultural reasons, chiefly to avoid the danger of overcropping and soil exhaustion, but it also facilitates the economical distribution and use of water.

The main Gezira area, under the agricultural supervision of the Sudan Plantations Syndicate Ltd. and the Kassala Cotton Company Ltd., has been cropped under the following schemes since it came into operation in 1925.

	Areas in feddans					
Years	*Tenants holding*	*Cotton*	*Millet*	*Legumes*	*Resting*	*Remarks*
1925–31. .	30	10	5	5	10	1929: millet 4·4 F., legumes 5·6 F.
1931–3 . .	34·4	10	4·4	..	20	Temporary, to facilitate change over.
1933 to date, basic . .	40	10	5	5	20	..
1933 to date, actual . .	40	10	5	1–2	24–23	..

The cropping scheme on the Abd el Magid Alternative Livelihood area, administered by Government, differs in several respects from these and is discussed separately later.

The agricultural and economic aspects of the crop rotations and cropping schemes in the Gezira are considered in Chapters XX and XXVII.

Millet is sown in late July or early August and watered until 31 October; legumes are sown in September and normally watered until 31 December; cotton is normally sown about mid-August and watered till 31 March (before 1936 until 10 April).

In all the above cropping schemes the whole of one 'number', that is, the area fed by one watercourse, is treated uniformly throughout its length, and in the main Gezira area carries only one type of crop, e.g. cotton, millet, or legume. This means that a tenant's holding is spread over several 'numbers', but it greatly simplifies the watering. During August and September the watering routine is considerably affected by the incidence of the rainfall and the vicissitudes of sowing and weeding, but once the rains are over, it is re-established, the normal intervals being:

Cotton: every 12 to 18 or 20 days, according to climatic conditions.
Millet and legumes: every 20 days.

'Numbers' under each type of crop are grouped in pairs drawing from the same minor canal. Of each pair, one is watering while the other is closed, so that there is an even draft on the discharge of the minor canal.

It will be seen that during October all crops are under irrigation; this is a season of rapid growth and also of high temperature, and as a result the demand for water usually reaches its maximum at this period. It is not possible to give actual figures for watering applied to the different types of crop, since the discharges are measured at the head of each minor canal, off which may draw 'numbers' under all three types of crop. Apart from seasonal and crop variations, the waterings required vary appreciably with the slopes and levels of the land in each 'number'. Where the slopes are insufficient or irregular, this water will not spread on the land sufficiently fast to cover the whole area within the allotted period, unless increased discharges are given to the watercourse.

The following table shows, for the years 1925–6 to 1944–5, the 10-day average waterings given, in m.^{3} per day, per feddan under crop and being irrigated. This is briefly termed the crop factor, and is of course an average over all crops. In October, for instance, it is safe to say that the cotton, at that season watered at about 12-day intervals, received rather more than the average, and the other crops rather less. Generally speaking, the table shows that an overall crop factor of 30 m.^{3} per day per feddan should usually suffice at the period of peak demand. These figures are for water supplied at the head of the main canal, and therefore include losses *en route*, which in the Gezira canalization may be estimated at 15–20 per cent., to the head of the watercourse.

It will be noted that the proportion of the gross area which is under crop is now only about 43 per cent., though if the area allotted to legumes were to be fully cultivated, this figure would rise to 50 per cent. This compares with the proportion of 66⅔ per cent. under crop in the original rotation.

Water Control and Distribution. The flow of water in a large canalization scheme, once started, must continue night and day as steadily as possible. Changes in discharges can only be made in steps of moderate size at reasonable intervals, with careful co-operation between the controlling staff throughout the scheme. From the start it was decided that to ensure satisfactory working and economy in water the system of water distribution in the Gezira should be quantitative, and this involved an exact knowledge and control of the discharges passing each regulator at all times. This has been achieved by the calibration of all regulators down to those in the minor canals, and, from the beginning, records have been kept of the daily discharges at all control points.

The water which will be required for each minor canal is normally assessed weekly by an Agricultural Inspector of the Concession Companies staffs. By a complete telephone system the water indents are passed to the local Irrigation Officer in charge of the subdivision concerned. In his office the figures are compiled and the totals passed upstream from subdivision to subdivision, each adding its quota, until the total demand, including an allowance for losses in transit, reaches the Resident Engineer at Sennar Dam, who makes any change required on the setting of the head regulator of the main canal. In case of emergency,

such as sudden rainfall, changes may be asked for at any time and are effected as soon as possible, compatible with safety.

While the first instalment of the scheme was under construction it was decided that the irrigation of field plots by night by inexperienced cultivators was not possible without risk of damage to the crops. To meet this difficulty a scheme was evolved whereby the field outlet pipes would be closed at night, and the continuing discharges into the heads of the minor canals would be stored within the channels themselves until the morning. The cross regulator on each of the various reaches of a minor canal is provided with an overflow weir in the centre of which is set the steel sluice-gate. The crest of the weir is set to a calculated height (some 16 to 20 centimetres) above the normal full supply level of the canal at that point. By day the field outlet pipes on irrigating numbers are open, and the regulator sluices are set so as to hold the full supply level in the canal. By night both field outlet pipes and regulator sluices are closed entirely, and the discharge entering the canal head raises the level in the first reach to some 30 centimetres above the full supply level, at which height the discharge spilling over the weir is equal to that entering the canal head. Thus the canal fills up, reach after reach, to night storage level. Before the tail reach has risen above this level the field outlet pipes are opened in the morning and the stored water is drawn off, the regulator sluices being opened in succession from the tail upwards.

The system, though simple, has one serious defect. The severe check to the velocity of flow of the water causes considerable deposits of silt, especially in the head reaches of minor canals, which have to be cleared every few years if the flow capacity of channels is to be maintained. Further, the land is deprived to some extent of the fertilizing effect of this silt.

Organization and Administration

As explained in more detail in Chapter XXVII (Blue Nile Province), the Gezira Scheme is operated in the form of a triple partnership, between the Government, the two allied Concession Companies, the Sudan Plantations Syndicate Ltd. and the Kassala Cotton Company Ltd., and the tenant cultivators. Their respective functions may be summarized as follows:

(*a*) *Government*. Provides the land, rented from its owners at 10 piastres[1] per feddan per annum, and allotted to tenants, without rent or land tax. Provides the water, by means of the Sennar Dam and Reservoir and various pump stations, and the canalization down to the minor canal.

Provides auxiliary services, such as public health, telephones, &c.

(*b*) *Concession Companies*. These direct and control the agricultural side of the scheme through a staff of resident inspectors, whose main function is to supervise the work of the tenants in watering, growing the crops, picking and bringing in the cotton, and clearing the land of the dead cotton plants at the end of each season. The Concession Companies keep individual accounts for each cultivator,

[1] 100 piastres=£E1·000. 97·5 piastres=£1.

and carry out the whole of the ginning, dispatch, and sale of the cotton.

The companies also maintain and operate a light railway system for cotton transport to their ginneries, and a fleet of cable ploughs, which each year plough and ridge the cotton areas for the succeeding year, on the tenant's behalf.

(c) *Tenants* are responsible for the whole of the agricultural work on their holdings, including the excavation and upkeep of the water-courses and lateral channels. Supplies made to them in kind, such as seed, and work done on their behalf, such as ploughing, are debited to them. Advances of cash are made to them at suitable periods by the Concession Companies, to meet their expenditure on sowing, weeding, picking, &c.

The whole of the food and fodder crops are retained by the tenants. From the gross proceeds received by the sale of the cotton are deducted the costs of ginning, transport, and sale, and the balance is divided, 40 per cent. to the tenants, to each according to the weight of cotton from his holding, and 60 per cent. between the Government and the Concession Companies, in proportions which may vary slightly, the present figures being approximately 38·5 per cent. and 21·5 per cent. respectively. Thus all three partners share in good or bad seasons.

The maintenance and operation of the reservoir and canalization is in the hands of the Sudan Irrigation Department, with headquarters at Wad Medani. The whole scheme is divided into four divisions, Sennar Dam, Wad Medani, Abu Ushar, and Western Gezira. The first is responsible for the operation of Sennar Dam and Reservoir, in accordance with the Nile Waters Agreement, and for the upper reach of the main canal. The others are Canalization Divisions, under which the scheme is further divided into subdivisions. Each of all these units is responsible for water control and for maintenance in its own area. There is also the Mechanical Division, which has under its charge the pumping stations at Muzeiqila and Qundal, on the main canal, irrigating land too high to be commanded by free flow, and those at Hag Abdullah and Wad en Nau, used in the months of May to July to raise water from the river and pass it into the canalization system for domestic supply, when the reservoir is too low to command the main canal head. This division also operates a large fleet of dragline excavators, graders, scrapers, and other plant, used for silt clearance from canals and upkeep of their banks. Finally, the Projects Division is responsible for design and the investigation of future developments.

Abd el Māgid Scheme

This area, of 38,000 feddans gross, is the latest extension irrigated from the Gezira Scheme. It was developed in instalments in the years 1937 to 1941. It draws its water-supply from the main canal by a separate branch canal taking off at Abu Ushar, and is sited on the extreme north-western limit of the present canalized area. In several important respects it differs from the main Gezira area, and therefore deserves separate description.

It has been developed primarily to provide a means of livelihood for part of the population formerly settled on the White Nile whose lands are inundated during the period of storage of water in the Jebel Aulia Reservoir. The basis of its organization and layout is cultivation by village communities, controlled by their own sheikhs. It does not come under the agricultural supervision of the Concession Companies, but is administered under a Board of Government officials, consisting of the Governor of the Province, as chairman, with the Directors of the Departments of Agriculture and Irrigation as members.

The individual tenant's holding is 18 feddans, in 3 plots of 6 feddans each, on 3 adjoining watercourses. The present standard scheme of cropping is as follows:

Per holding		
Plot No. 1:	Cotton	5 feddans
	'Free', i.e. cropped as desired by the tenant: usually millet	1 feddan
Plot No. 2:	Millet	3 feddans
	Leguminous crop	3 ,,
Plot No. 3:	Resting	6 ,,

This proportion of cropping is as intensive as that on the main Gezira area in the years 1925–30, and considerably more so than that now in force. The total area under cultivation per tenant, 12 feddans, is, however, less at Abd el Māgid than in the main area, where it is generally 16 feddans. Experience indicates that, in the Sudan, 12 to 16 feddans under all crops is as much as one tenant can handle. In increasing the proportion under both food and leguminous crops, and decreasing that under cotton, as compared with the main area, it was intended to ensure a sufficiency of food for the tenant's family and his animals, and at the same time to maintain the fertility of the land by mixed farming. In so far as in some of the war years food crops have been increased at the expense of the leguminous crop, this intention has not been carried out in full, and manuring to restore fertility is being applied.

The area on three adjoining watercourses forms a unit, for agriculture, irrigation, and administration, and is under the control of an Agricultural Sheikh. Each watercourse irrigates 30 plots of 6 feddans each or 180 feddans in all; thus the sheikh controls in all 540 feddans. He and his people live in a village, sited in or reasonably near to their cultivation. The sheikh is responsible for the supervision and co-ordination of the work of his people, both in watering and in all agricultural operations, and he himself has to co-operate, in water control, with the irrigation staff controlling the canals, and also with his neighbour sheikh, whose area is watered in alternate periods with his. The 36,000 feddans of the scheme are divided into ten sections; in each section all the Agricultural Sheikhs form a committee which meets at regular intervals under the guidance of the Inspector of Agriculture to discuss all aspects of the operation of the scheme and to deal with agricultural and irrigation offences. All ten committees in joint session form the Council of the whole scheme.

As elsewhere in the Gezira, all crops other than cotton are normally

the full property of the tenant, to be disposed of as he likes. The cotton is taken over by weight at collecting stations, and transported, ginned, and sold under arrangements made by Government. After deducting the total costs of these operations from the gross proceeds of sales, the balance is divided, 60 per cent. to the Government and 40 per cent. to the tenants, each receiving his share according to the weight of cotton he has brought. In the financial arrangements provision is made for the retention in years of good yield and prices of part of the tenant's share in an Equalization Fund, to be used to maintain the rate of payment to them at a reasonable figure in years when the return from their labours would otherwise be too low. Another notable feature is the Tenants' Welfare Fund, financed by a levy of up to 10 milliemes per kantar of seed cotton (315 rotls) payable as to 60 per cent. by Government and 40 per cent. by the tenant. This fund may expect an annual revenue of about £E400. It is administered by a locally elected committee, under a small nominated Board of Trustees, for the general benefit of the population dependent on the scheme.

The villages in the scheme are sited and laid out so as to combine as far as possible healthy living conditions with reasonable nearness to the areas cultivated by their occupants. Centrally sited is the headquarters, at Abu Guta, where are the main market and shopping centre, schools, court, and dispensary, as well as agricultural and administrative offices, and quarters for Government staff, including the Inspector of Agriculture. Here, and at other suitable points in the scheme, are garden plots cultivated under separate tenancies and conditions, which supply fresh vegetables. Areas of forest to give timber for buildings, and also fuel, have also been provided at convenient sites.

The layout of the minor canalization, watercourses, and plots is shown in Figs. 246 and 247. The standard length of watercourses is 2·8 kilometres, each watering 180 feddans, as compared with 1·4 kilometres and 90 feddans in the main Gezira area. Each watercourse can nevertheless complete the watering of its area in the usual period of 7 days, because watering continues day and night; there is no night storage of water in the minor canals as in the main Gezira area.

No insuperable difficulties have been encountered in irrigation on this system, though it is not easy to ensure even watering over all the plots. The advantages of the layout are very considerable. The capital expenditure on minor canals is greatly reduced, and less land is taken up by them and the roads adjoining them. On the maintenance side, operation of the canals is more simple and the absence of night storage, with the water held up for considerable periods, reduces considerably the silt deposited in the channels.

IV. Irrigation by Pumps

Historical and General

Irrigation by pumps drawing from the rivers was introduced into the Sudan early in the present century on a small scale. It has since steadily developed, and now takes a very important place in the economic life of the country. The chief developments have been on the main Nile from

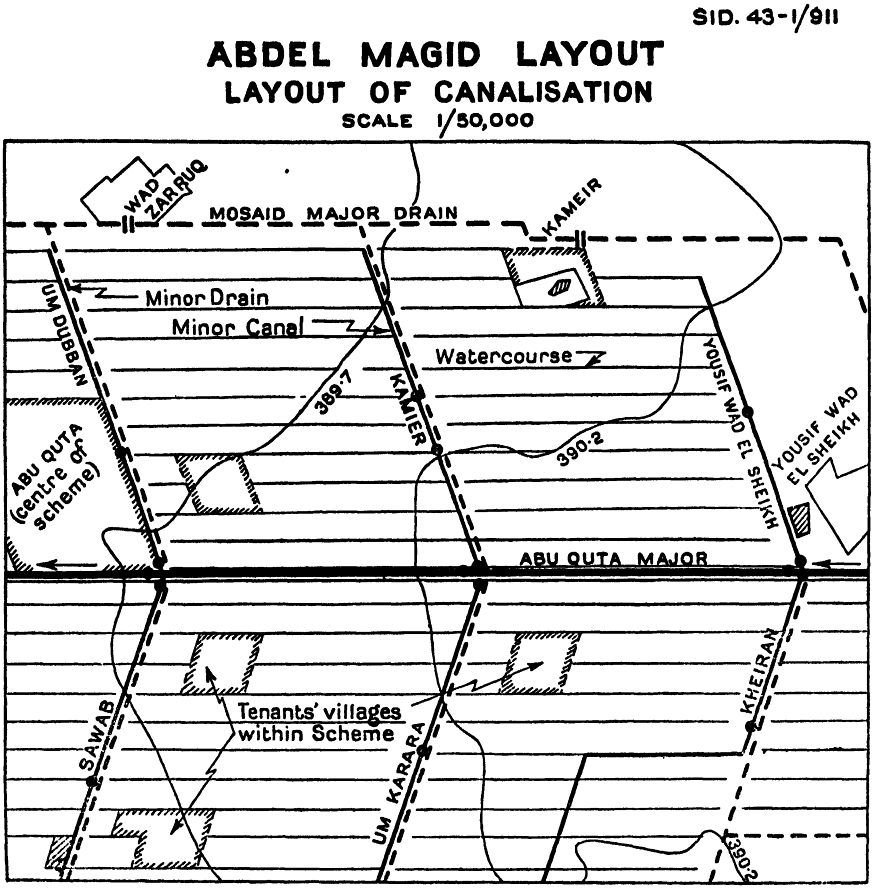


FIG. 246.

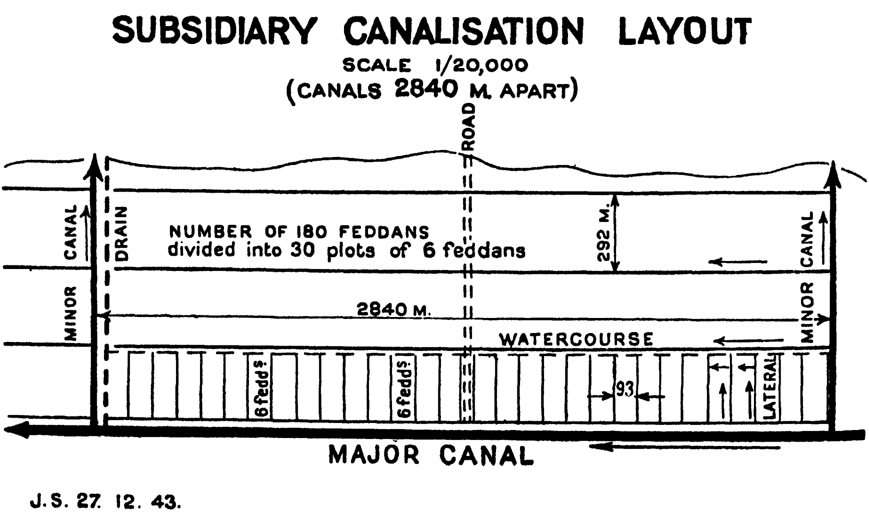


FIG. 247.

the Egyptian boundary below Wadi Halfa in the north, up to Khartoum, some 970 miles, and on the White Nile as far south as Kosti, 200 miles above Khartoum. On the Blue Nile, with its enormous variations in discharge and level between high flood and low river, conditions are not so suitable, and development here has been on a limited scale, while on the Atbara the complete drying up of the river after December practically precludes pump irrigation altogether.

On the long stretch of river formed by the White Nile and Main Nile there are no areas of good land sufficiently large and at such levels as to justify a weir or barrage across the river for free-flow irrigation as in the Gezira. Therefore all systematic irrigation must be by lift-pumps or 'sāqiya'. There are certain advantages in this. The irrigated areas are well distributed over this vast extent of country; since each scheme is a self-contained unit, there is great flexibility in development and no large organization is needed for supervision and control.

Existing schemes include examples of the following types:

(i) Government schemes—cultivated by tenant cultivators, ranging in size from 300 to over 8,000 feddans.
(ii) Private schemes—with tenant cultivators. These are generally also of a fair size.
(iii) Co-operative schemes.
(iv) Private schemes worked by the owner or his agent. Most of the smaller schemes are of this type.

Generally speaking, where conditions are reasonably good the capital cost per feddan of land canalized in a pump scheme, including the pumping equipment, is comparable with that of a large free-flow scheme such as that in the Gezira (including the Sennar Dam and Reservoir). The annual running costs of a pump scheme, per feddan, are of course considerably higher, and therefore the crops grown must be such as will produce an adequate return.

Irrigation by pumps in the Sudan has for many years been controlled by a system of licences. There are two classes of these: 'perennial' licences, on which water may be drawn all the year round, and 'flood' licences, limited to the period 15 July to 31 March. The licence states the gross area of land comprised by the scheme and also the number and size of pumps. The latter, in effect, limits the total cultivable area, according to the system of cropping adopted, and allowing for a proportion of resting land. The gross area of the scheme is always greater than the cultivable area, since some land is always required for roads, canals, &c., and in many schemes certain areas included within the boundaries are left uncultivated because they are of poor quality land or too high.

During the early years of this century the net total areas irrigated increased slowly, until by 1925 they had reached 22,500 feddans under 'perennial' licences and 16,000 feddans under 'flood' licences. In 1926 there was issued the report of the Nile Commission, later incorporated in the Nile Waters Agreement of 1929. This provided that there should be no limitation on the areas which might be irrigated by pumps in the Sudan from 15 July to 31 December in each season, but that after the

latter date, on areas in excess of certain limits, the water used should be replaced in the river by the release of compensation water from Sennar Reservoir. These limits are:

1 January to 28 February	38,500 feddans
1 March to 15 July	22,500 feddans

The rate of compensation is 800 m.³ per month, on every feddan watered within any month. In compiling the records of irrigation and assessing the compensation water to be released, the actual areas irrigated are taken on all Government schemes, and on private schemes served by pumps with inlets of more than 14-in. diameter. In the case of the smaller private schemes the areas watered are assumed to be those in the following table, prepared by Mr. C. E. Dupuis, former Inspector-General of Irrigation in the Sudan, and generally known by his name:

Pump inlet diameter (in.)	*Approx. discharge (m.³ per hour)*	*Equivalent area for water compensation (feddans)*
2	13	5
3	37	12
4	52	19
5	81	35
6	142	51
7	197	71
8	272	98
9	340	122
10	425	153
12	612	220
14	833	300

Pump irrigation from the waters of the Nile and its tributaries thus involves the use, for individual profit in the case of private schemes, of part of a public asset, the water stored in Sennar Reservoir. The licensing and operation of all pump schemes is now controlled under the 'Nile Pumps Control Ordinance 1939' and regulations issued under its provisions. This ordinance set up as the controlling authority the Nile Pumps Control Board, composed as follows:

Chairman. Civil Secretary or his representative.
Members. Legal Secretary. Financial Secretary. Director of Economics and Trade. Director of Agriculture and Forests. Director of Irrigation. } or their representatives.
Two Sudanese Members appointed to represent private pump owners in the Blue Nile and Northern Provinces respectively.

In addition, Governors of Provinces may attend when matters are being considered with which they are concerned. The Secretary is found by the Department of Agriculture, which maintains the detailed records of the licensing and also the compensation water debits of all the schemes. The Board normally meets four times a year.

Applications for the approval of new schemes, or the extension of existing schemes or for alterations to plant, have to be accompanied by certain specified plans and other particulars. These, and also applications for transfer renewal or cancellation of existing licences, are submitted in the first place to the Governor of the Province concerned. He forwards them with his comments to the Board, which decides whether or not they can be approved, and if so, on what conditions. The Board's powers include control of the system of rotation of crops on all schemes and the right of inspection to see that the regulations and conditions of the licence are properly carried out.

Normally licences are issued for the following periods:

Pumps up to and including 4 in.	5 years
Pumps over 4 in. and up to 10 in.	10 years
Pumps over 10 in.	15 years

But these may be reduced where special circumstances warrant a shorter period. During the war, to increase food production, a number of emergency licences have been issued, both 'flood' and 'perennial'. These are for two years only, but may of course be renewed. Many will probably disappear at the end of the emergency period, but probably a proportion of the more efficient schemes will be given normal long-term licences. The date from which licences run has now been standardized at 1 May in any year. The annual fee charged for a pumping licence varies with the size of the pump used, that on a 'flood' licence being half that on a 'perennial' licence for the same size of pump. Details are shown in the Appendix at p. 632. Gross areas licensed in 1944 were as follows:

Gross Areas Licensed

	Perennial feddans	*Flood feddans*	*Total feddans*
Normal licences	105,018	59,354	164,372
Emergency licences	458	15,332	15,790
TOTALS	105,476	74,686	180,162

180,162	feddans.	Gross licensed areas 1944.
173,949	"	Gross areas of pumps in operation in 1944.
6,213	"	Not in operation in 1944 owing to breakdown of plant or other reasons.

Net Areas under Irrigation at Various Periods during the Restricted Season—Normal and Emergency

	Perennial feddans	*Flood feddans*	*Emergency feddans*	*Total feddans*
January, 1944	34,266	12,636	5,165	52,067
February, 1944	33,388	12,636	5,165	51,189
March, 1944	31,407	12,636	5,165	49,208
April, 1944	15,078	..	1,033	16,111
May, 1944	21,918	..	1,033	22,951
June, 1944	25,462	..	1,033	26,495
1–15 July, 1944	29,732	..	1,033	30,765

The extent to which pump irrigation from the Nile has developed is shown by the statement for the year 1944 at p. 617.

Irrigation

From the agricultural point of view there is no fundamental difference between the irrigation on a large free-flow scheme such as the Gezira and that on a pump scheme. In most cases it is convenient to run the pumps from 12 to 16 hours per day only, and thus night watering is avoided; this contributes to economy of water and the reduction of running costs. Against this, the land on which pump schemes are laid out is often more irregular in slope and level than on a large scheme, and this makes even water distribution less easy, though the day-to-day control is more direct, since in most cases the canal system is short and fairly simple.

An important point in any project for pump irrigation is the pump site on the river. The ideal conditions may be stated as follows:

(i) Deep water close to the bank at all stages of the river.
(ii) Permanency—subject neither to erosion of the bank, nor to silting in front of the inlet.
(iii) A bank face of steep slope so as to involve the shortest possible lengths of suction and discharge piping.
(iv) Immediately behind the bank, ground as high as the higher parts of the irrigable area, to avoid canalization in high banking.
(v) Location immediately adjoining the irrigable area.

Of these, (i) and (ii) are essential, and a number of sites have in the past had to be abandoned on account of defects under these heads, not apparent when the schemes were first constructed, which developed in the course of time. The other conditions chiefly affect the capital cost of a scheme per feddan of cultivable area, and many sound schemes are now in operation in the Sudan which fall far short of the ideal in one or more of these conditions. Few, indeed, are the sites which even closely approach the ideal; one of the best is the Hag Abdullah station, on the Blue Nile, which from 1926 to 1935 irrigated 16,500 feddans, cultivated as part of the Gezira Scheme. The first four conditions were met almost completely, while under the fifth the irrigated area was a fairly compact block about 20 kilometres long by an average width of 5 kilometres, stretching north and west from a point only a few hundred metres from the pumping station. This station, like others on the Blue Nile, has to work at a very high lift during the season of low river, the maximum being about 20 metres. At high flood this is reduced to about 10 metres. Since 1935 irrigation water has been supplied to the whole of this area from the main canal by the Muzeiqila pump station, with a lift of not more than 2½ metres. The Hag Abdullah station now is used only to supply 'domestic' water into the main canalization during the summer months when the reservoir cannot feed the main canal.

Pumping schemes on the White Nile have considerably increased in recent years. They are described in more detail in Chapter XXVII (Blue Nile Province), and it is here only necessary to note the advantageous conditions which result from the existence of the Jebel Aulia Reservoir,

List of Pumps in Operation as at 31 December 1944

	Pump suction																Schemes under			Gross area feddans
	5" and under	6"	7"	8"	9"	10"	12"	14"	16"	18"	20"	22"	24"	27"	30"	33"	T.E. l.	Perennial l.	Flood l.	
Northern Province																				
Government schemes	8	3	..	2	..	3	..	4	5	11	..	1	3	..	..	2	..	42	..	32,220
Private schemes .	51	24	4	30	1	20	19	9	1	1	..	..	..	..	4	..	54	95	15	53,291
Total . .	59	27	4	32	1	23	19	13	6	12	..	1	3	..	4	2	54	137	15	85,511
Khartoum Province																				
Government schemes	23	3	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	27	..	454
Private schemes .	36	5	..	2	..	3	3	1	1	..	1	1	1	..	..	..	2	46	6	17,283
Total . .	59	8	..	2	..	4	3	1	1	..	1	1	1	..	..	..	2	73	6	17,737
Blue Nile Province																				
Government schemes	4	..	..	2	..	..	..	2	2	..	..	..	..	..	11	..	4	17	..	25,050
Private schemes .	32	5	..	1	..	1	2	3	3	2	1	7	..	2	..	..	4	24	31	45,571
Total . .	36	5	..	3	..	1	2	5	5	2	1	7	..	2	11	..	8	41	31	70,621
Upper Nile Province																				
Government schemes	..	2	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	3	..	62
Private schemes .	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	3
Total . .	1	2	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	4	..	65
Equatoria Province																				
Government scheme	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	15
GRAND TOTAL .	156	42	4	37	1	29	24	19	12	14	2	9	4	2	15	2	64	256	52	173,949

which is filled during late July, August, and September, stands full at a constant level until early February, and is only partially emptied by the end of March, when the normal irrigation season in this part of the country ends.

The chief field for still further development of pump irrigation is probably in the Northern Province. The main engineering difficulties to be faced are: first, to find reasonably suitable pump sites and then to ensure their permanence, and second, the irregularity of the land in the areas proposed for cultivation. Both of these tend to increase the capital cost of development per feddan. A further difficulty is the high lift required in many cases during the low-river season. All this emphasizes the importance of the economic aspect of the schemes in this district; the cash value of the crops produced has to be fairly high to give an adequate return on the capital invested and meet the costs of transport and leave a fair profit for the cultivator himself. Mention may here be made of irrigation by pumps from wells. This is only used on a very limited scale mainly because wells are rare which will yield water at a sufficient rate to justify even a very small pump. Pumping involves also imported fuel and lubricants and expert care and maintenance, and thus higher costs than those of the native 'sāqiya'. The use of this method is likely always to be limited to sophisticated districts and crops of high intrinsic value.

V. Flush Irrigation

Flush irrigation is essentially a development from natural flooding. It is the simplest form of irrigation, being merely a single soaking of the land during the season of high flood. On this the crop is sown, and the success of the method depends on the capacity of the soil for absorbing the water and later yielding it again to the roots of the crop as it grows. In this respect soils vary greatly; in the northern and central Sudan most land of reasonable agricultural quality will hold enough water from one flooding to mature a crop such as millet; long-period crops such as cotton can only be grown on particular types of soil.

The method has the merits of simplicity and of covering the land with a deposit of fertilizing silt. Its disadvantages are that it depends on adequate flood levels, and that as compared with systematic irrigation it generally gives lower yields and needs more water per feddan.

The outstanding examples of this type of irrigation in the Sudan are in the deltas of the Gash and Baraka rivers, though strictly speaking there is no 'irrigation' on the latter in the sense of definite control of the flooding, either in quantity, period, or areas watered.

Both these streams rise in the mountains of Eritrea; both are dry for the greater part of the year, but during the rainy season come down in violent spates of heavily silted water. Both have formed large deltas of their own silt deposits, which provide soils of great depth and fertility. Both grow excellent crops of long-staple cotton as well as very fine millet and other food crops. The topography, climate, and agriculture of these areas are described in the Kassala Province chapter.

The Gash

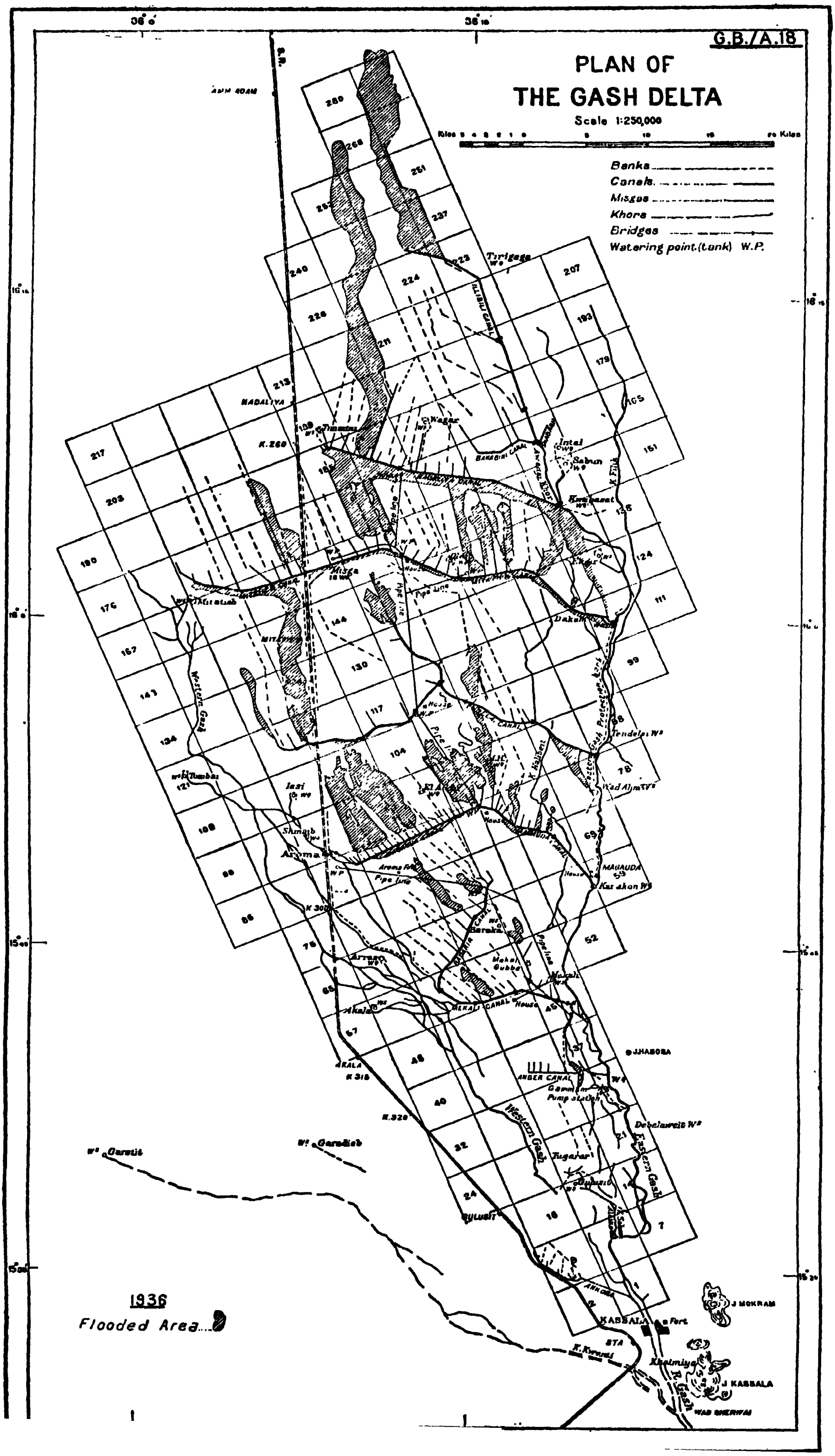
The Gash river is in flow usually from early July to late September; extreme dates recorded are 10 June to 18 October. Its flow is torrential and highly variable; it may increase from a mere trickle to a high spate of 800 m.^{3}/sec. within a day or even a few hours. The total discharge for the season has varied from about 140 million m.^{3} to about 1,260 million m.^{3}. The water is heavily silted, up to 1 part in 60.

The Gash Delta (Fig. 248) stretches for well over 100 kilometres north and north-west from Kassala town, with a general slope of about 1/1,000. Formerly about 6 kilometres north of Kassala, the Gash divided into two main channels, the Eastern and Western Gash Khors. About 1910, as the result of the construction of a regulated basin astride the Western Gash, this channel silted up. Since then practically the whole discharge has passed into the Eastern Gash Khor. Like all deltaic streams, this channel is continually silting its bed and, by overflow, its banks. In time the channel runs on the crest of a self-formed ridge; when this becomes too high an avulsion takes place to one side or the other, and the stream flows down the adjoining hollow to begin anew the building-up process.

The areas watered by natural overflow are covered by a heavy growth of grass bush or thick forest, and they can only be cultivated with much labour and expense. Farther away from the Eastern Gash Khor, and mainly in the northern half of the delta, are large areas of fairly clear land. The canalization of the delta has been laid out to give a sufficient but controlled supply of water to these areas. Fig. 248 shows the general layout. Each canal has a masonry head-regulator to control its supply, which is distributed to the branch channels, known as 'misqa', through small regulators. Each year only one-third to one-half of the total area commanded by a canal is scheduled for irrigation, the rest being left unwatered. The 'misqa' which it is intended to use are divided into two groups. 'Misqa' in the first group are opened as soon as it is judged that the flood is well established, generally in July, and run for up to 20 days or more according to the flow in the river. The 'misqa' in the second group follow later. From the 'misqa' the flush of water spreads out over the ground, as shown in Fig. 248. The land near the 'misqa' is of course more heavily watered than that on the fringes of the flooded areas, and this latter is usually allotted for cultivation with millet.

The ideal watering is from 12 to 20 days, but good cotton has on occasions been grown on land wetted for 6 days only. The Gash soil absorbs and holds water very readily; it has been found thoroughly soaked to a depth of 13 metres after a normal watering, and samples taken 18 inches below the surface in May were still damp and cohesive from a flooding in the previous September.

The area irrigated for cultivation, in round figures, ranges from 40,000 to 60,000 feddans each year, according to the flood. Although compared with systematic irrigation the system is primitive, experienced supervision is needed both in agriculture and in engineering, provided by staff from the Departments of Agriculture and Irrigation under a special organization for the work in the delta. (See also Chapter XXV (Kassala Province).)



G.B./A.18
PLAN OF
THE GASH DELTA
Scale 1:250,000
Banks
Canals
Misgas
Khors
Bridges
Watering point.(tank) W.P.
1936
Flooded Area
KASSALA
J KASSALA
J MOKRAM
Western Gash
Eastern Gash
R. Gash
Fort
Pump station
Western Gash

The Baraka and Tokar

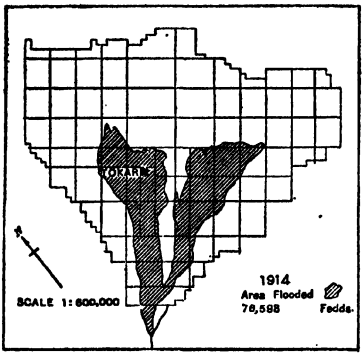
The Baraka is even more torrential and irregular than the Gash. The normal flood season is from mid-July to mid-September, but the actual flood consists of isolated spates each lasting from a few hours to 3 or 4 days. During a spate the rate of discharge may be enormous, approaching 1,200 $m.^3$/sec. on the highest actually measured. These arrive at quite irregular intervals: at other times the bed is almost dry. The silt content during spates is much higher even than in the Gash and has been recorded up to 1 part in 10.

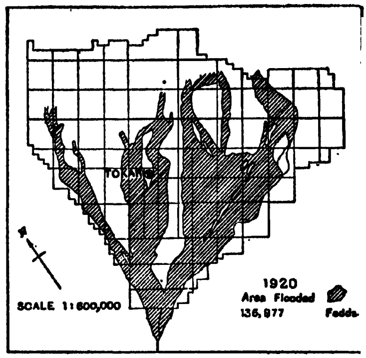
From the head of the delta, 50 kilometres from the coastline, the waters flow in no really permanent channels; large changes in course may occur during a single flood or even a single spate. Only a part of the whole delta is flooded in any one year even if the total flood is a large one. Over a period of years this flooded area will swing across the delta from one side to the other, though for the last twenty-three years the tendency has been definitely to the east, as shown in Fig. 249.

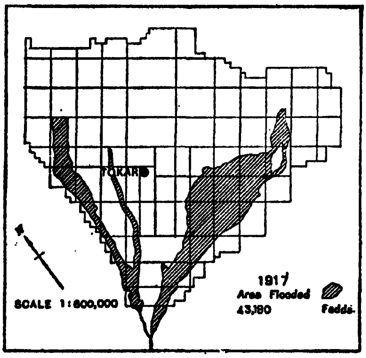
In the past attempts have been made to guide and to some extent control the spread of the flood, with the object of watering the largest possible area and giving a rotation of flooding on the different sectors of the delta. None have been permanently successful. Schemes have been proposed for comprehensive control works, including masonry regulators, at the apex of the delta, and large guide banks to force the waters to take the desired course. The estimates of cost were heavy; the upkeep clearly would be very difficult and expensive, and the prospects of success were most uncertain. In the event, and almost certainly very wisely, it was decided to let the Baraka take its own course and accept the large and well-flooded, though very variable, area which it provides without any trouble or expense. This conclusion was reinforced by the weather conditions in the delta during the flood season. Strong winds, without local rains, raise constant and very severe dust storms, which not only make mere existence appallingly unpleasant and outside work often almost impossible, but cause heavy drifting of sand and silt, which would give endless trouble on regulating works and might even completely prevent their successful operation. (See also Chapter XXV, commencing at p. 706, and Fig. 249.)

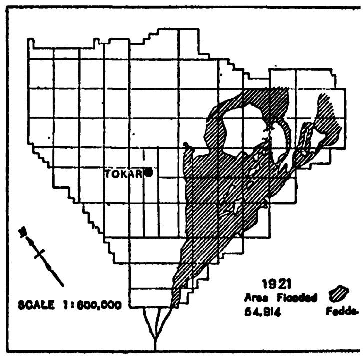
VI. Basin Irrigation

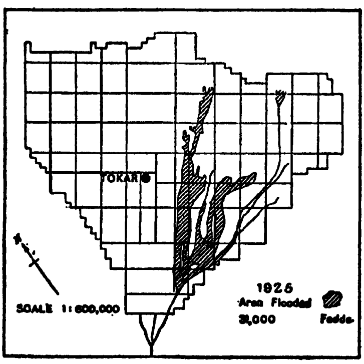
Whereas in flush irrigation the water is released to spread over the land, in basin irrigation it is poured into a depression—the 'basin'—and then, after the ground is sufficiently soaked, returned to the river. The home of basin irrigation was the Nile valley in Egypt, where the annual flood overflowed the river banks to cover the depression between the silted river course and the desert hills on either side. Stages of development were the construction of banks to divide up the depression so that water could be retained on the areas desired, development of supply and drainage channels, and use of regulators for control in place of the primitive making and breaking of earth banks. Basin irrigation in Egypt is of immemorial age, though scientific development to the present complete system dates only from the second half of the nineteenth century.

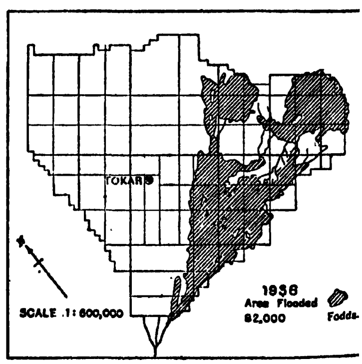

TOKAR
SCALE 1:600,000
1914
Area Flooded
76,588
Fedds.

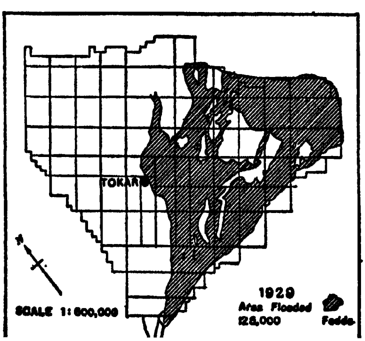

TOKAR
SCALE 1:600,000
1920
Area Flooded
136,977
Fedds.

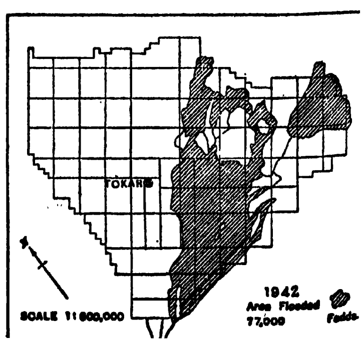

TOKAR
SCALE 1:600,000
1917
Area Flooded
43,180
Fedds.


TOKAR
SCALE 1:600,000
1921
Area Flooded
54,814
Fedds.


TOKAR
SCALE 1:600,000
1925
Area Flooded
31,000
Fedds.


TOKAR
SCALE 1:600,000
1936
Area Flooded
82,000
Fedds.


TOKAR
SCALE 1:600,000
1929
Area Flooded
126,000
Fedds.


TOKAR
SCALE 1:600,000
1942
Area Flooded
77,000
Fedds.

In the Sudan the Nile valley is not subject to annual flooding as in Egypt, and conditions favourable to basin irrigation exist only where chance depressions are found—all in the Northern Province and spread over two reaches. The southern, or Shendi, reach stretches from the Sabaloka gorge to near Atbara: the rainfall is slight, 2 to 4 in. annually. The northern, or Dongola, reach stretches from Merowe[1] to Kerma: the rainfall is negligible, nothing to 2 in. annually. The only area of a size comparable to an Egyptian basin is the Kerma plain.

There is no evidence of any extensive basin cultivation in early days. More recently, old 'Turkish' canals show that a few small areas were in cultivation, mainly on the west bank between Shendi and Kiteiyab and near Debba. Affat basin, for example, is known to have been in use in Dervish times. After his first visit to the Sudan Sir William Garstin recommended (1899) that the reach between Khartoum and Berber be developed by a series of large basins on the Egyptian plan: on further study he reported (1904) in favour of large pumping stations, with possibly a few selected basins, whose cost would be very high in proportion to results.

The Kerma plain was discovered, as possible agricultural land, in 1905, and development on basin lines started on a large scale in 1909. From 1907 extensive surveys were made in the then Dongola province and a number of small basins opened. In 1909 the potential area of basin land was put at 120,000 feddans, of which Kerma accounted for two-thirds. At this period some at least of the old Turkish canals north of Shendi were also in use. Need for food crops during the 1914–19 war spurred agricultural development; three basins in Dongola were converted to pump irrigation; the Shendi reach was surveyed, and the present basins really date from about 1917. After the war there was little advance: difficulties at Kerma, the scattered location and small size of the other basins, and the inception of the Gezira Scheme all turned attention from basin irrigation. Sir Murdoch MacDonald, in *Nile Control*, 1920, gave the basin area in the Sudan as 80,000 feddans (compared with 1,200,000 feddans in Egypt): no actual measurements existed and this figure was deduced from statistics of flood irrigation, including basins, supplied by the Department of Agriculture. In considering water requirements as between Egypt and the Sudan the Nile Commission (1925) reported that these basins were understood to be not capable of much improvement and of little agricultural value: conditions did not favour development on Egyptian lines. Up to 1928 basins were controlled technically by the Egyptian Irrigation and administered by the province authorities. From 1928 they went, in effect, on to care and maintenance only. In 1940 technical control passed to the Sudan Irrigation Department. The series of good floods from 1932 to 1938 revived interest. A programme of betterment was started in the Shendi area in 1939, and a committee was appointed in 1940 to report on further possibilities of Kerma basin.

Fig. 250 shows the basins now in use. Eleven basins in the Shendi area, ranging from 2,000 to 8,000 feddans each, can be expected to water some 30,000 feddans on a fair flood—the range of actual results being from 6,000 feddans on a bad to 41,000 feddans on a very good flood. In

[1] Pronounced Merrowy.

the Dongola area six small basins round Debba may give 3,000 feddans on a good flood (nothing on a bad flood): there are three major basins—Letti (from 1,000 to 8,000 feddans), Argo (from 1,000 to 7,000 feddans), and Kerma (at present from 4,000 to 25,000 feddans); as Kerma is so very variable, an expectation of about 40,000 to 50,000 feddans and a range of 5,000 to 70,000 may be assumed. Only the three major Dongola basins have a system of demarcation, into 10-feddan plots, which covers only the probable floodable area.

In Shendi about 80 per cent. of the flooded area is cultivated, millet and chickpea being the main crops. In Dongola as a whole a much smaller proportion (under 10 per cent. in 1942) goes under crops, which include beans, lupins, wheat, chickpea, and barley: the rest of the flood area is forest or grazing land, though in Kerma considerable areas are cultivated by lift from wells, the replenishment of whose subsoil water is greatly helped by the flooding.

At present (1943) the twenty basins are served by some 245 kilometres of canals and drains and have nearly 100 kilometres of banks and 40 regulators, besides bridges.

Modern Egyptian practice is to have basins in one area interlocked in a complicated network of channels and divide banks so that water may be suitably retained and, by using drainage from high to fill successively lower sections, economically used. The Sudan basins, small and irregular, do not lend themselves to this development. In effect, therefore, each basin has its feeder canal, one or more drains or escapes to release the water, cross banks at the lower end (and occasionally at intermediate points) to hold up the water to sufficient depth, and guide banks at intervals to keep the water within bounds. Banks running across the basin are called 'salība' and those running with the basin (i.e. parallel to the river) 'tarrad'. Canals and drains usually have masonry regulators to facilitate opening and closing, and where basins are subdivided these banks have regulators to let the water through from high to lower 'hōd' or compartments.

The cycle of irrigation is simple. On arrival of the flood at a suitable level the feeder canal is opened and the basin allowed to fill to good irrigation level—known as 'T.R.' from the Arabic 'tammam rai'. This level is generally considered to be that which covers the ground to an average depth of from 70 cm. to 1 metre. After holding 'T.R.' for as nearly as possible 30 days, the water is released as the river level falls by opening the drain. Where the basin is divided into 'hōd' 'T.R.' is held first in the upper (higher) section; after 15 to 20 days the regulators in the divided bank are opened and water passed through to the lower 'hōd', raising it in turn to 'T.R.'

The success of basin irrigation depends on the flood. The relative levels of the basin lands and the river water in flood must be such that the basin can be filled, and the flood must hold these levels long enough to cover the period required for filling. As the depth of water required in the basin is about a metre, and in the basin stretches the Nile rises some 7 metres in flood, variations in the annual floods are reflected and magnified in the basin results: a basin which requires a 7-metre rise is a poor proposition

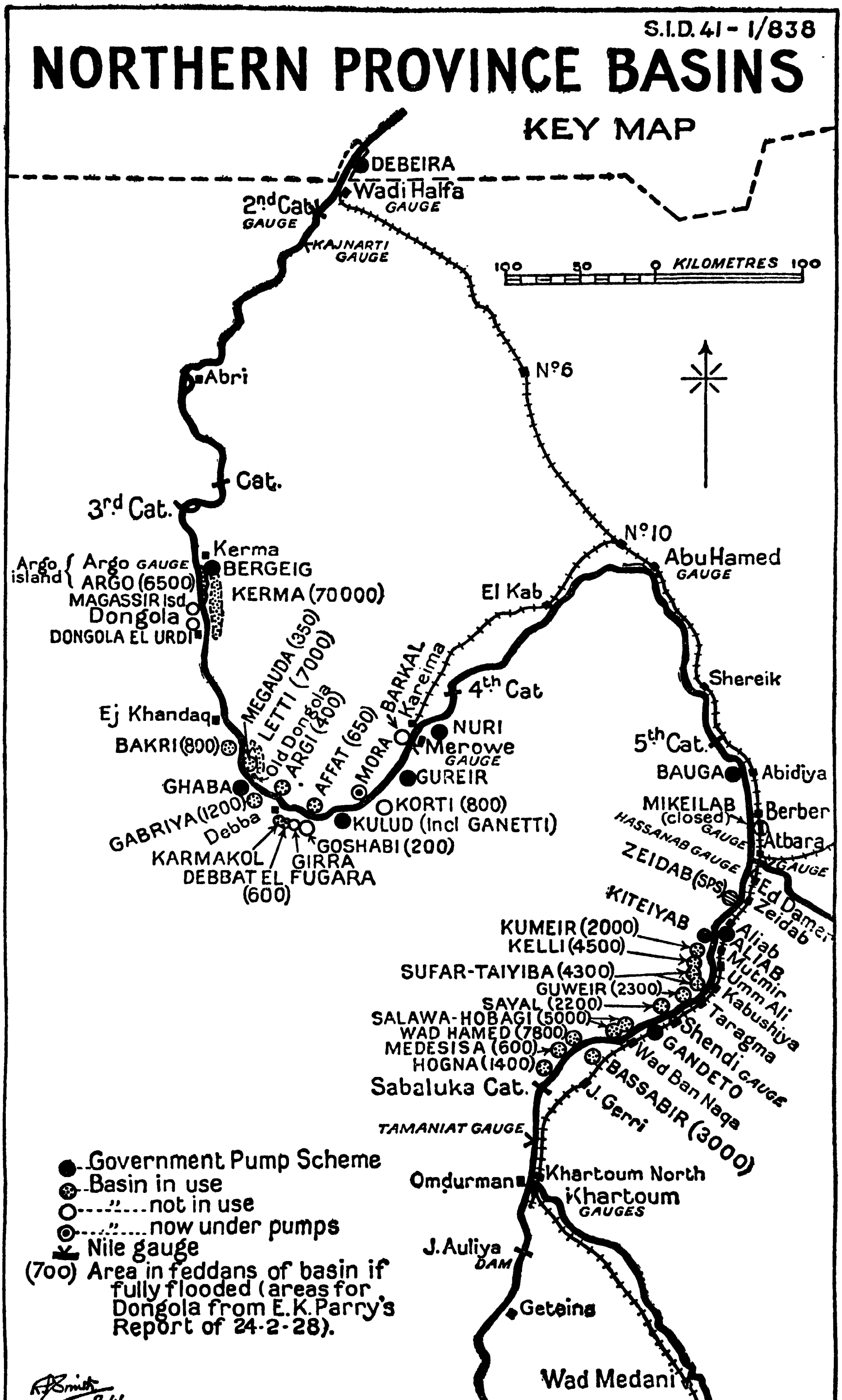

S.I.D. 41 - 1/838
NORTHERN PROVINCE BASINS
KEY MAP
KILOMETRES
DEBEIRA
Wadi Halfa GAUGE
2nd Cat. GAUGE
KAJNARTI GAUGE
Abri
No 6
Cat.
3rd Cat.
No 10
Abu Hamed GAUGE
Kerma
BERGEIG
Argo island
Argo GAUGE
ARGO (6500)
MAGASSIR Isd.
KERMA (70000)
Dongola
DONGOLA EL URDI
El Kab
MEGAUDA (350)
LETTI (7000)
Old Dongola
ARGI (400)
AFFAT (650)
MORA
BARKAL
Kareima
4th Cat
Shereik
Ej Khandaq
BAKRI (800)
NURI
Merowe GAUGE
GUREIR
5th Cat.
GHABA
GABRIYA (1200)
Debba
KORTI (800)
KULUD (Incl GANETTI)
GOSHABI (200)
KARMAKOL
GIRRA
DEBBAT EL FUGARA (600)
BAUGA
Abidiya
MIKEILAB (closed)
Berber
HASSANAB GAUGE
Atbara GAUGE
ZEIDAB (SPS)
Ed Damer
Zeidab
KITEIYAB
KUMEIR (2000)
KELLI (4500)
Aliab
ALIAB
SUFAR-TAIYIBA (4300)
Mutmir
GUWEIR (2300)
Umm Ali
SAYAL (2200)
Kabushiya
SALAWA-HOBAGI (5000)
Taragma
WAD HAMED (7800)
Shendi GAUGE
MEDESISA (600)
GANDETO
HOGNA (1400)
Wad Ban Naqa
Sabaluka Cat.
BASSABIR (3000)
J. Gerri
TAMANIAT GAUGE
Government Pump Scheme
Basin in use
" not in use
" now under pumps
Nile gauge
(700) Area in feddans of basin if fully flooded (areas for Dongola from E.K. Parry's Report of 24-2-28).
Omdurman
Khartoum North
Khartoum GAUGES
J. Auliya DAM
Geteina
Wad Medani
9.41

FIG. 250.

compared with one which will flood on a 6-metre rise. Isolated spates are of no value. A sufficient period of steady high level is needed. The Nile gauge at Shendi has been recorded since 1908 and is centrally placed for the Shendi basins. Mathematical analysis of the flood gauges shows that the probabilities are:

	Low basins	*High basins*
Good years .	2 in 6	1 in 6
Fair years . .	1 in 6	1 in 6
Bad years . .	3 in 6	4 in 6

(Low basins are those which flood readily, while high require a good sustained flood level.) These figures are rough guides only, as basins differ considerably. There is no similar key gauge applicable to the Dongola reach, but expectation there is certainly no better than for the Shendi 'low' basins.

The only way to overcome this dependence on flood levels would be artificially to control them by construction of weirs or barrages across the Nile—as has been done in Egypt.

Water required is assessed in Egyptian practice at 170 cubic metres per feddan per day for 40 days—actual consumption varying from 80 to 190 between minimum and maximum years—or 6,800 m.^{3} per feddan. Of this about half is escaped and half is absorbed by the ground. No detail data are available for the Sudan, but discharge observations in Seleim canal (Kerma basin) since 1940 indicate a requirement of from 6,000 to 8,000 m.^{3} per feddan.

Kerma basin, as the only really large area, merits a separate note. The original plan was for a private concession of some 12,000 feddans in the northern end. Development of the whole area as a basin started in 1909 and aimed at 80,000 feddans. Seleim canal was dug, drawing from the Nile opposite Dongola and turning north through the southern section of the basin, and a 'salība' constructed at Bergeig, about four-fifths of the way north. At first 20,000–25,000 feddans were watered. In 1911 it was realized that more drainage was required and a line of cuts led from the end of the canal to Bergeig. A soil survey revealed the best land in the north, beyond Bergeig bank, moderate land in the centre, and poor and sandy soil in the south. In 1912 Seleim canal was widened to its present bed width of 20 metres and a system of banks, drains, and regulators constructed in the Bergeig area.

During the early years the better soils gave magnificent crops and hopes were high. But these promising areas rapidly ceased to yield. Egyptian fellahin were brought in to improve agricultural methods, without staying the rapid deterioration of the land. The project was only saved from extinction by the discovery of the lucerne-like 'kiteih' (*Trigonella laciniata* Linn.) which gave excellent grazing. As a result development was slowed down, and in fact confined to gradual extension of small canals to distribute water from Seleim and cuts and banks to guide the flood through natural hollows and across rises. It appeared that where a sufficient silt deposit could be obtained, the land recovered its pristine fertility—but deposition of silt over 50,000–70,000 feddans is a slow process. In 1924 a regulator was built at Kadruka, midway between Seleim and Bergeig, where banks

were formerly built, and annually broken, across depression. Later Hamednarti cut was dug from Khor Argo, to form a second supply canal; it was of limited value.

The works now comprised Seleim canal, starting with 20-metre bed width but diminishing throughout its 21·5 kilometres length as side channels took off, the Hamednarti cut (5-metre bed width and 700 metres long), the Kadruka regulator and banks, various small scattered cuts and banks, the Bergeig 'salība' and regulators, and the system of drains and regulators in the north, which was but seldom flooded.

In 1940 a committee was appointed to report on the area. Its first report defined the agricultural and level surveys and maps which would be required before the problem could be really attacked. Owing to war these have not yet been possible. In 1942 pump schemes were proposed, and in 1943 one was constructed covering some 4,500 feddans north of Bergeig 'salība': as this cut out the existing system of drains, a new escape regulator was built just south of Bergeig.

For further details see also Chapter XXVI (Northern Province).

VII. Sāqiya and Shadūf Irrigation

Before the introduction of pumps, lift irrigation was carried on by means of water wheels, worked by bulls, and 'shadūf', worked by men. Although irrigation by pumps has greatly extended, the old methods are still widely used in spite of their disadvantages, especially in the Northern Province, where, as has been noted already, all irrigation except that in the basins during the flood must inevitably be by lift.

The Sāqiya

The 'sāqiya' or Persian water-wheel, known in the Sudan in its typical form as the 'Dongola' 'sāqiya', has probably remained little changed for centuries. Its design, in principle, is simple. A large wooden wheel (cf. Figs. 251 and 252) with wooden teeth on the outer rim is mounted on a vertical wooden shaft, from the upper part of which projects a horizontal arm to which are yoked two bulls (sometimes only one). This wheel drives a similar but smaller wooden-toothed wheel, mounted on a horizontal shaft, the other end of which carries a large open-spoked wheel with a wide periphery. The latter carries two parallel endless ropes, joined by spacing-bars, to which are attached a series of earthenware jars, petrol tins, or other containers. The loop of the parallel ropes dips into the water below the 'sāqiya', and as the wheel revolves, the pots are filled in succession and carried to the top of the wheel, where, as they pass over it, they spill their contents into a trough, whence the water flows away to the field channels.

The 'sāqiya' can raise water from 3 to 8 metres, and is easily adjustable for varying lifts by shortening or lengthening the ropes. As a water-lifting device it is mechanically very inefficient, but it has certain points in its favour which account for its astonishing persistence of life.

It is entirely made of local materials, wood, rope, and leather. Unless in the containers, there is no metal whatever used in its construction. As

the result of its age-long use the art of its construction is widely known. Minor repairs can usually be made by the owner on the spot, and experts for major repairs are easily available in districts where its use is general. It employs as its motive power animals which are bred in the country. It is cheaper in first cost than an engine and pump of equivalent capacity, and requires neither imported fuel and lubricants, nor trained mechanics which have to be paid for in hard cash. Finally, being a self-contained unit, it permits of individual holdings, cultivated independently.

FIG. 251. A 'matara' or Persian water-wheel working from a well, Gharb el Gash, near Kassala (*photo G. J. Fleming*).

Against this there is a great loss of power in friction, and much water lifted is spilt back into the well, especially if a strong wind is blowing, in spite of the use of screens. When used on the river, as the level falls in the summer, the ropes have to be lengthened, and the output in water decreases just when it is most badly needed. At the same time, the adit from the river to the well has to be cleared and deepened repeatedly. Finally, nearly half the crop produced has to go in fodder for the bulls which operate it, unless some alternative supply is available. The area which it can irrigate is small, even under the most favourable conditions, and therefore its use on the river is limited to lands within a few hundred metres of the bank.

The area which a water wheel can irrigate varies considerably with the lift. At high Nile, with a lift of about 2·0 metres, probably 4–5 feddans can be kept under crop; during the winter, 2½ feddans, and at low river, when the weather is also at its hottest, from 1–1½ feddans is about the maximum.

Where the lift is very great, or where a sandbank has cut off the direct water-supply to the well, a double wheel or 'kalatod' is sometimes used. But this is rare, as these can seldom be economic. A 'sāqiya' working from

a well is known as a 'matara'; where the yield of the well is sufficient this has the advantages that the installation can be more permanent than is possible on the river bank, and the variation in water level is generally much less, both in rate and in total range.

Improvements in the Dongola 'sāqiya' have been tried along several lines —better bearings for the shafts to reduce friction; standardized design to simplify assembly and replacement of parts, and improvements in the rope, buckets, and trough to reduce wastage of water. None have been generally adopted to date—mainly because of the innate conservatism of the owners, who rather like to hear the characteristic creaking groan of the wheels, which tells them that the 'sāqiya'-boy is keeping the bulls at their work.

Improved types have been introduced on a very limited scale, generally under Government direction. The iron 'sāqiya' has cast-iron bevel gear-wheels, and the lifting wheel carries a linked chain and galvanized iron buckets. It is efficient, but has never become popular.

The 'tabūt', often termed the Egyptian 'sāqiya', uses a metal double-sided wheel dipping into the water, driven by metal gears within which are formed volute compartments. As the wheel revolves, the water is raised until it flows to the centre and is discharged round the axis into a side trough. Variants of this use separate volute-shaped scoops framed together for stiffness. These types have a high rate of delivery, but their lift is limited to rather less than half the diameter of the wheel, say 2·5 metres at most. All types of wheel employing metal gears require heavy and well-built foundations and wells. They are thus expensive in first cost and suitable only where the permanence of the site is assured.

The following table shows the numbers of water wheels registered as in use in the Sudan in recent years by provinces:

	1933	*1938*	*1943*
Blue Nile Province	231	210	339
Darfur Province	..	..	1
Equatoria Province	..	..	..
Kassala Province	161	168	255
Khartoum Province	368	326	355
Kordofan Province	9	33	29
Northern Province	8,070	9,054	9,456
Upper Nile Province	..	..	1
TOTALS	8,839	9,791	10,436

Of these, all in Darfur and Kordofan, most in Kassala, and a small proportion in other provinces, draw from wells and not from the river. It will be noted how, even now, the home of the 'sāqiya' is in the Northern Province, where indeed it provides a larger proportion of the irrigated area, though its predominance is seriously threatened by the small diesel-engined pump, from 4-in. diameter suction upwards. On the edges of the Jebel Aulia Reservoir, where the water level is constant from October to February, low-lift water wheels, often of the 'tabūt' type, are finding an increasing field of usefulness.

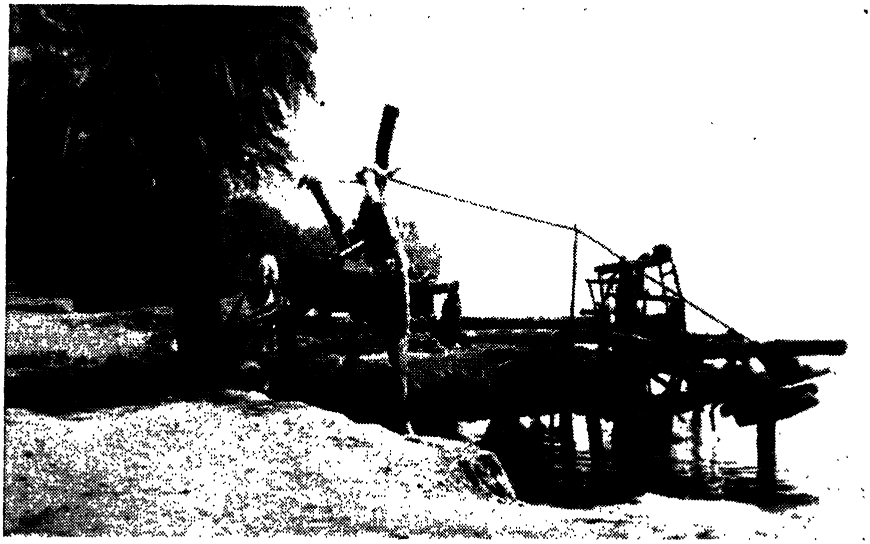


FIG. 252. 'Sāqiya', Nuri, Northern Province, operating at high Nile level: note small lift (*photo R. G. Fiddes*).

FIG. 253. Irrigating by 'shadūf' from a pool on River Rahad, near Mafaza (*photo G. J. Fleming*).

The Shadūf

This is a very primitive but quite effective means of lifting water by man-power through a limited height, usually from a pool, canal, or river. It is cheap and simple to construct and maintain. It consists (see Fig. 253) essentially of two wooden posts or pillars of dried mud, supporting a cross bar on which is pivoted a long wooden lever. To the shorter end of the lever is fixed a stone or ball of dried mud; this acts as a counterpoise to a rod or rope and dipper attached to the longer arm. Below this end is the inlet channel from which the water is to be lifted. The rod is seized high up and pulled down until the dipper enters the water. The full dipper is then allowed to rise, pulled up by the counterweight, until it reaches the level of the upper channel, into which it is emptied by a sideways tilt. The dipper may be a bag of leather, but the 4-gallon petrol tin is commonly used. Lifts of up to 3 metres can be obtained, but the greater the lift the fewer the strokes per minute. At a lift of 2·0 metres a shadūf worked by one man would have an output of about 3–5 $m.^3$ per hour or, say, 24–30 $m.^3$ per day, which would suffice for one-half to two-thirds of a feddan of vegetables, the type of crop for which it is most commonly used. The total number of shadūf in use in the Sudan is not exactly known, but the area they water cannot exceed in all a few thousand feddans. Many of them on the Nile are only used during the flood season, when the lift to the level land on the banks is small, to grow a catch crop. Nevertheless they form a useful addition to other lifting appliances, since they can so easily be installed, operated, and maintained.

Appendix

Annual Licence Charges for Pumps

Size of pump	*Perennial licence* £E *m/ms*	*Flood licence* £E *m/ms*	*Remarks*
2″	0·150	0·075	Pumping licence fees are payable to the District commissioner concerned by the licensee on the issue of the licence and upon the 1st of May in every subsequent year during which the licence is in force.
3″	0·260	0·130	
4″	0·470	0·235	
5″	0·720	0·360	
6″	1·280	0·640	
7″	1·800	0·900	
8″	2·450	1·225	
9″	3·040	1·520	
10″	3·820	1·910	
11″	4·700	2·350	
12″	5·510	2·755	
13″	6·520	3·260	
14″	7·500	3·750	
15″	9·100	4·550	
16″	10·370	5·185	
17″	11·720	5·860	
18″	13·120	6·560	
19″	14·720	7·360	
20″	16·200	8·100	
21″	17·980	8·990	
22″	19·600	9·800	
23″	21·470	10·735	
24″	23·330	11·665	
25″	25·430	12·715	
26″	27·620	13·810	
27″	29·850	14·925	
28″	32·000	16·000	
29″	34·180	17·090	
30″	36·450	18·225	

CHAPTER XXII

ANIMAL HUSBANDRY

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GENERAL

THE Sudan is essentially a country of domestic animals, but animal husbandry in the strict sense of the word is almost non-existent. Large areas of the country are waterless except for a brief period during the rains, with the result that enormous flocks and herds are restricted to limited areas, chiefly along the rivers and near towns, which areas in consequence have become dangerously over-grazed. As yet, little has been done to improve indigenous strains, a procedure much preferred to that of importing foreign blood. The Sudan's domestic animals have proved themselves to be well suited to the very severe local conditions and are of a type and quality well deserving of up-grading.

There are few people in the Sudan who are not dependent on animals to some extent or other, be it for food or transport or livelihood. Very substantial revenue is received annually from the export of livestock, hides, and clarified butter, and situated as the country is there is no reason why trade in animal products should not be capable of further steady development in the post-war years.

The evolution of mixed farming is proceeding slowly. It must, however, become standard practice in the future in all irrigated areas and will undoubtedly come to be increasingly important in many areas now predominantly pastoral.

INDIGENOUS BREEDS OF LIVESTOCK

I. CATTLE

Many minor types of cattle exist in the Sudan, as would be expected in a territory of roughly a million square miles, nearly the whole of which is fitted for little but nomad pastoralism. Broadly speaking, however, all can be divided into two type-groups, namely Arab or northern and Nilotic or southern, the first named being herded by Arab nomads north of about the tenth parallel of latitude and the latter by pagan Nilotics to the south. It is impossible to estimate the number with any close approximation, but it is thought that 3 million head is a conservative rather than a liberal guess. Of these, some tens of thousands of the Arab type are used for agricultural purposes, mainly turning water-wheels along the more northerly reaches of the Nile, while the remainder run freely at grass. Many Arab beasts are occasionally called upon in nomad

areas to carry small loads of domestic goods for their owners, but no Nilotic cattle perform any kind of work whatsoever.

The older of the two main types is undoubtedly the Nilotic, which is to be classed a 'sanga', i.e. a cross mainly derived from the Palaeolithic Hamitic Longhorn ox and the Long-horned (or, more correctly, Lateral-horned) zebu that infiltrated from Asia into Africa in early dynastic times. This type (Figs. 33, 43, and 254) was presumably pushed back behind its present northern boundary by the steady pressure of Muslim invasion that persisted throughout the Middle Ages. Limited tribal intercourse, and conscious or

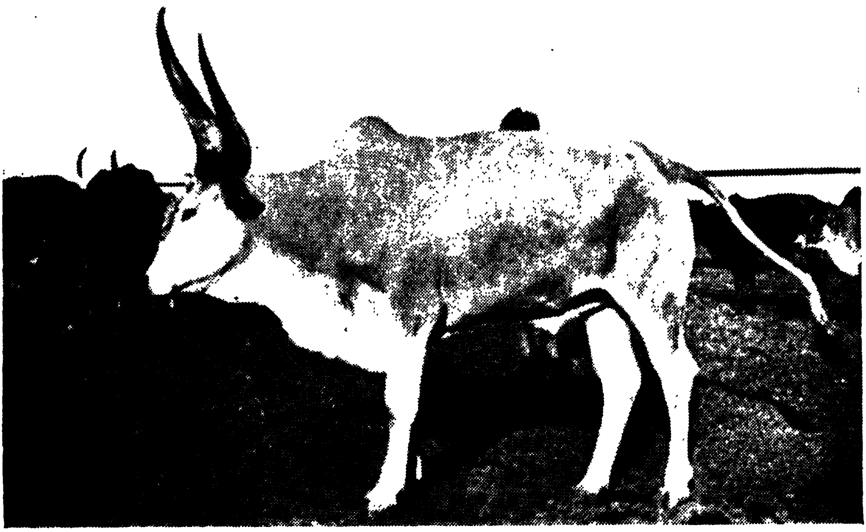

FIG. 254. Dinka steer. An example of a Nilotic breed.

unconscious selection, resulted in the development of local varieties that would roughly correspond to 'breeds' in the usual sense of this term, and in a few localities it is still possible to make out local types in which certain colours or minor features of conformation predominate. On the whole, however, breed characteristics have already become inextricably confused by a few decades of relative intertribal peace and wide freedom of movement. Nevertheless, all Nilotic cattle still retain their group characteristics of long massive horns and a relatively small hump.

The Arab cattle of the north (Fig. 255) are of a far more recent type. They are doubtless a mixture of all groups and types that have gradually worked their way down through Africa since prehistoric times, but they most closely resemble the most recent introduction, namely the short-horned zebu, that is thought to have been introduced into Africa by the Persian invaders of Egypt in the seventh century A.D.[1] All these cattle have a large hump and relatively short horns, and, although individual beasts vary considerably, no minor types are in general distinguishable. To this

[1] Probably a reintroduction as Zebu cattle are depicted in Egypt in tombs of the Twelfth Dynasty. V. pages 19 to 21.—*Editor.*

general statement, however, there is one notable exception, namely what may conveniently be called the Northern Riverain type, that now inhabits the banks of the Blue and White Niles for 200 miles or so south of Khartoum. This is a light blue-grey beast with dark blue 'points', which is said to have originated on the Blue Nile, whence it extended down that river and up the White Nile to make good the destocking that occurred during the reign of the Khalifa Abdullahi in the later years of the nineteenth century. The relative uniformity of this type is probably due to its having sprung from a very small herd, which was afforded unusual

FIG. 255. Darfur-type bull. Another example of the Arab cattle of the north.

opportunities for expansion because the truly pastoral tribes kept very much in the hinterland during the earlier years of the Anglo-Egyptian reoccupation.

In addition to the two foregoing main type-groups, there is a third which is at least worthy of mention. This is the dwarf beast which is found only in the Nuba Mountains of southern Kordofan. It is undoubtedly an early type, closely allied to the so-called African Shorthorn, which has long remained inbred and unchanged in the isolation it has until recently shared with its owners in an almost inaccessible pagan 'island' surrounded by Arab tribes.[1]

The differences between northern and southern cattle are more than merely morphological, since it is regularly observed that neither type thrives in the other's environment; in fact a large proportion of Arab cattle will die if maintained in the south during the rains. The economic potentialities of the two types also differ. Nilotic cattle grow noticeably larger, in some districts commonly exceeding 1,200 lb. in weight (adult

[1] The origin of Sudan cattle is further discussed by Lucas in Chapter III. —*Editor.*

males), whereas Arab cattle rarely attain 1,000 lb. This, however, may merely be referable to more generous and greener pasture during their growing years. Nevertheless, in spite of better pasture, the cows are much poorer milkers than Arabs, since the latter, if provided with adequate rations, will in many cases give a yield not far short of the good milking breeds of Europe. Conversely, southern beef is better than northern, provided always that slaughtering is carried out locally, since the rigours of lengthy transport cause southern cattle to fall away very seriously.

Such small amount of study as has been devoted to 'improvement' has been directed towards milk production, since Arab cattle—the only ones ever called upon to work—are quite suitable for any work they may have to do. The point at issue has been the relative merits of 'grading up' by the use of imported bulls, and selection from indigenous stock. Attempts at grading up were early abandoned, because nearly every imported European bull died of *Theileria annulata* infection so soon after arrival that no cows were served, and the progeny of the few that did not die proved quite incapable of surviving except under the highly artificial conditions obtainable only in one or two European-managed dairies near Khartoum. Selective breeding has nowhere been in progress long enough for its potentialities to be fully assessed, but since Arab cows, even when selected almost at random, will show a profit if they are but adequately fed, there is no doubt that internal selection is the policy to follow.

The very fact that native cows show such great promise, provided they are adequately fed, is, however, in itself a warning that no great scope for improvement exists. Under pastoral conditions they have little chance, for meteorological reasons, of being adequately fed. The openings for good milking cows will therefore be limited to relatively few centres where high living conditions, and especially supplementary feeding with concentrates, can be assured.

The beef qualities of Sudan cattle will be discussed under a later heading.

II. Sheep

It is impossible, in the space available, to attempt to give even a superficial description of all the varieties of sheep that exist in the Sudan. There are probably a score of recognizable 'breeds' with fairly constant characteristics, together with innumerable crosses that have become so stabilized in the areas in which they are maintained that they might almost be regarded as breeds. It is, moreover, impossible to make more than an honest guess as to numbers. However, in consideration of the numbers listed for purposes of taxation, where taxation on such a basis is practised, and of the observed rough proportion of sheep to cattle, an estimate of 5 or 6 million would probably not be excessive.

The physical characters that all Sudan sheep have in common are a hairy coat, pendulous ears, roman nose, long legs, and long fleshy tail. The first two of these features are absolute, while the others are increasingly variable in order named, and only to be expressed in relative terms as between one breed and another.

Inconstant features are legion, for example: some breeds are hornless

while others are horned, and wide variations occur in the size and shape of the horns; great variations in colour occur, including pure white, black, or brown and all ranges of particolouring; the coat may be short, long, fine, or coarse; variation in weight (adult males) extends from 25 lb. to 150 lb. or more. A large number of less obvious features are also to be seen, covering a wide range of variation.

Fortunately, it is not quite so hopeless as it might seem, in spite of inconstancy and diversity of physical characteristics, to formulate a

FIG. 256. Desert ram, export type.

reasonable basis for classification, since, once all characters of all varieties are fully grasped, it is evident that there are only three, or at most four, group-types. These can be delimited, not only on account of their physical features but also in relation to their environmental distribution. For convenience of description they may be termed: (i) Desert or Arab, (ii) Upland or Zaghawa, (iii) Nilotic or Southern, and doubtfully (iv) Northern Riverain.

The Desert Sheep (Fig. 256) is a large, long-legged, bistre-brown sheep with occasional white particolouring. It has a boldly convex face, long ears, long thick-rooted tapering tail, and short to medium coat of relatively fine texture. When 'pure' it is probably hornless, as most individuals indeed are, but horns of all sizes, from vestiges to well developed, are not uncommon; these are of the classical, ribbed, spiral 'ram's horn' type. Adult males in good condition weigh up to 150 lb. or over. The ewes are good milkers, yielding as much as 5–6 lb. daily (more than the average southern cow). It is the best sheep in the country in every way.

This type, as the proposed name would suggest, is herded by nomad Arabs in the non-riverain areas west of the White Nile and east of the main Nile. At the boundaries of its typical semi-desert habitat it impinges on the other three types, and a number of 'breeds' have become more or less fixed from inter-mixtures.

The Zaghawa Sheep (Figs. 257 and 258), named after the Zaghawa tribe of nomad Arabs, is of medium size, with relatively short ears, very long black hair, and a relatively short, slender, white-tipped tail. All males are heavily horned, the horn being flattish in section, almost unribbed, and standing

FIG. 257. Zaghawa wether.

out horizontally from the head with a slight downward sweep and only a partial twist in the length. The face is not so convex as in the Desert sheep. Adult males weigh up to 75 lb., but the ewes are poor milkers. The Zaghawa is, by general consent, a coarse sheep.

Its essential habitat, to which it is still largely confined so far as the Sudàn is concerned, is northern Darfur, but it extends well beyond the western boundary into the upland country of French Equatorial Africa. Owners of desert sheep are in general antagonistic to the introduction of Zaghawa blood into their flocks, but a certain amount of crossing has occurred in northern Kordofan and central Darfur, with resultant parti-coloured 'breeds'. The area in which most crossing seems to have occurred is the west bank of the Nile north of Omdurman, where black long-haired sheep are quite commonly seen intermixed with those of the Northern Riverain type.

The Nilotic Sheep (Fig. 259) inhabits the whole of the Sudan south of about the twelfth parallel of latitude. Between about the tenth and twelfth parallels one may thus see Nilotic sheep running with Arab cattle. It is a very small, short-legged, animal with a very short, fine coat, approximating that of a smooth-coated dog in texture. The body colour is basically white, but

FIG. 258. Zaghawa-type sheep.

FIG. 259. Dinka sheep.

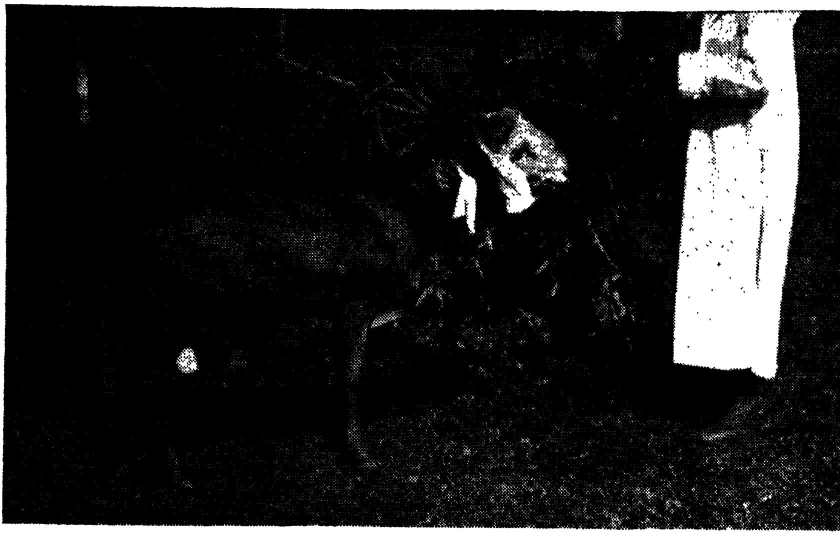

FIG. 260. Gezira-type ram.

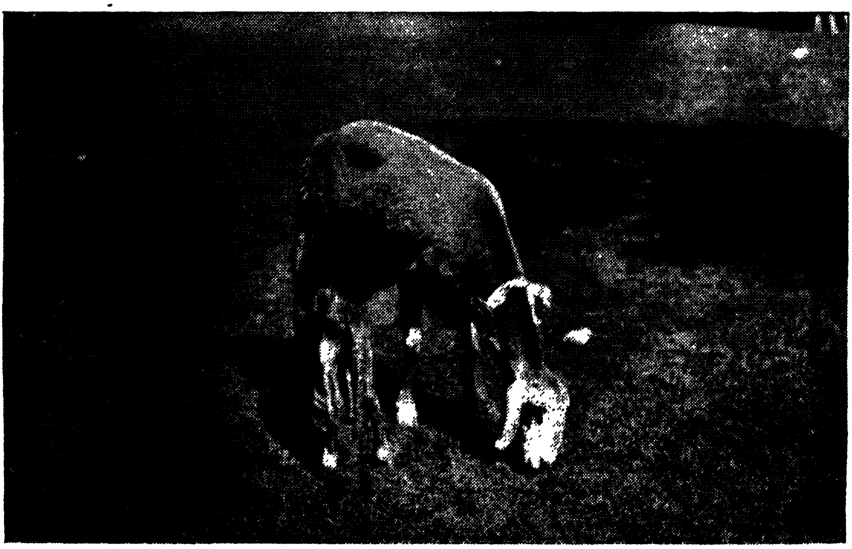

FIG. 261. Gezira-type ewe and lamb.

normally splashed with patches of black and tan. Small horns, of either the spiral or horizontal type, may or may not be present, and the males usually have a longitudinal ruff of coarse hair running along the under side of the neck. A full-grown Nilotic ram may weigh no more than 25 lb. The ewes give very little milk; often insufficient to rear their lambs.

The Northern Riverain Sheep (Figs. 260, 261, and 262) is very doubtfully a basic type, but is more probably a mixture of the Desert and Nilotic types. Desert sheep do not thrive in a riverain environment, and it

FIG. 262. Gezira sheep.

seems probable that the Nilotic type, which is suited to streams and marshes, has slowly worked its way northwards (or resisted pressure which in the hinterland has pushed it southwards), effecting crosses of varying degrees in the process. It is an indeterminate, medium sort of sheep, with medium length of leg, moderate boldness of facial profile, and fairly long ears. Its coat is relatively short, and tends toward particolouring on a light background. Adult males weigh up to 80 lb., being larger on the main Nile than along the Blue and White Niles. The ewes are fairly good milkers, giving 3, 4, or 5 lb. as one progresses from south to north. The Riverain sheep is described as a 'type' because, although it is probably a mixture, it can be recognized as what it is by anybody who knows the country's sheep.

The origin of the first three main types is obscure, and cannot profitably be discussed in small compass. Whatever their origin, however, there seems little doubt that it is from them that all existing breeds have sprung.[1]

[1] It seems probable that existing Sudan sheep are descended from the two Asiatic horned species *Ovis longipes* and *O. platyura*, and that the type here described as Nilotic is fairly pure *O. longipes* which seems to have entered the Sudan from Egypt earlier than the fat tail. Cf. Lucas in Chapter III.—*Editor.*

FIG. 263. Nubian goat, male.

FIG. 264. Nubian goat, female, with twin kids.

III. Goats

Wherever any domestic animal can live, the goat will thrive. It is therefore found throughout the Sudan, being invariably herded with sheep, which are almost as hardy and ubiquitous. As regards numbers, all that can be said is that in the northern half of the country there are about as many goats as sheep, while in the south there are probably a few less. A reasonable guess would put the total at perhaps 5 millions.

Many nondescript cross-bred goats exist, but there is no difficulty in analysing the population as a whole into three main groups, two of which are very distinctive in type. These may be classed as (i) Nubian, (ii) Desert or Upland, and (iii) Nilotic. The salient features of these are as follows.

The Nubian Goat (Figs. 263 and 264) is the most numerous and most widely distributed of all, being found almost everywhere north of about the twelfth parallel of latitude, and extending south of this line in some places. It constitutes the bulk of the goat population in riverain and urban districts, and is at least as numerous as the Desert goat in the more distant pastoral areas.

Typically it is long-legged, with long black hair, and long, drooping, light grey or speckled ears, turning outwards in their lowest third. Both sexes carry medium-sized, back-sweeping horns, which are simple in the female, but tend to be slightly twisted in the male. Mane, beard, and wattles are rudimentary. Males stand about 28 or 30 inches high at the shoulder and weigh 30–35 lb.; females are slightly smaller. The milking quantity of the nannies varies a great deal, and is probably mainly dependent on the quality of the available browsing or pasture. Probably about 3 lb. is an average daily yield, in addition to what the kid is allowed to take.

The Desert Goat (Fig. 265) is not so widespread or so numerous as the Nubian, since it is less popular in riverain areas, but away from the Niles it covers much the same range. It is also much the same size, but of lightish grey colour, often splashed with brown, with short coat, and rather smaller and straighter ears than the Nubian. Both sexes have horns, those of the male being large, horizontal, and twisted. The beard of the billy is usually well developed, often being bifid. All males, and to a lesser extent the females, carry a diffuse bushy mane which extends some little way along the back. Generally speaking, individual Desert goats show wider divergence from the standard type than Nubians, and the nannies are not such good milkers.

The Nilotic Goat is much more variable in detail than either of the other types, probably because certain characters have become emphasized in various localities in virtue of a more restricted range of movement. All local sub-types, however, have roughly the following features in common: The animal is only about half the size of the two other types, and shows great variety of colouring, including all proportions of white, black, and bright tan. The coat is very short, the beard and mane rudimentary, and the ears short. Both sexes usually carry horns, but even in the male these are very small, and in the female they may be absent. The typical horn

is only 2 or 3 inches long, erect, and with the point turned slightly forwards. The nannies yield only a few ounces of milk daily.

With a knowledge of the characters of the three foregoing main types, a fairly accurate guess can usually be made at the origin of the many indeterminate specimens that are seen in most areas.[1]

FIG. 265. Desert goats.

IV. CAMELS

All Sudan camels are of the one-humped, or Arabian, species and are distributed throughout roughly the northern half of the country. The semi-desert breeding areas, which are occupied by camel-rearing nomads, extend from the northern frontier down to about the 15th parallel of latitude, but working camels are regularly employed down to about the 13th parallel. There are, of course, slight local and seasonal fluctuations in these southern limits. No serious attempt has ever been made to estimate numbers, but, since over 400,000 adults are listed for taxation in areas where this form of assessment is practised, it is probable that the total amounts to three-quarters of a million.

The camel, as a species, seems to have undergone less differentiation over a long period than any other domestic animal. So far as can be elicited from historical records, the camel seems to have started its association with man in prehistoric times as a nondescript beast of burden, and about all that has happened since is that a few local strains have grown heavier while others have grown lighter.[2] In fact, if it is permissible to speak of

[1] The origin of Sudan goats is not clear, but they are probably derived from *Hircus mambricus*, *H. thebaicus*, and *H. reversi*, remains of which have been found in Egypt. Cf. Lucas, p. 22.—*Editor.*

[2] There is something very odd about the scarcity of records of the camel in the tombs of ancient Egypt. Petrie gives records of its occurrence in the Ist, XIXth, and XXVth dynasties, but its general use as a beast of burden seems

'types', it is certainly not reasonable to describe more than two, namely the pack and the riding types. Within these types, however, there are a few local strains which show certain distinctive minor features with sufficient constancy to be regarded as 'breeds'.

The Pack Animal is represented by two breeds, or, more correctly, the type contains only one distinctive breed, the Rashaidi, which can be differentiated from the total mass. Pack camels other than the Rashaidi are sometimes given a number of names, usually those of the tribes by

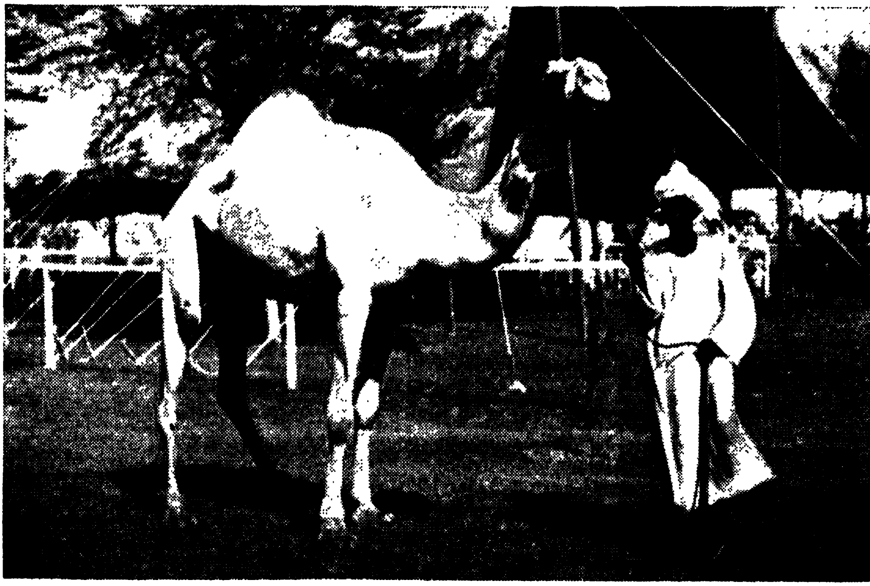

FIG. 266. Baggage camel, female.

whom they are bred, but more commonly—and more correctly—they are merely referred to as Arab camels.

The Arab camel is a large, heavily built beast, with the capacity for developing a relatively large hump. It is sandy-grey in colour and is to be seen throughout the country wherever camels are called upon to do pack work. Good specimens weigh up to 1,000 lb. Such a camel is virtually incapable of moving at anything but a slow walk, even when not loaded, but at this pace it will regularly carry a load of 600 lb. 15 miles a day; exceptional individuals will carry half as much again.

The Rashaidi camel is, unfortunately, a much rarer breed, being reared only by the Rashaida tribe north of Kassala town. It is a sturdy, relatively short-legged beast, not quite so heavy as the Arab, but capable of carrying nearly as heavy a load at a much smarter pace. If necessary it can even trot. Its distinctive feature, apart from its stocky build, is a marked pinkish-red colour.

not to have occurred until about A.D. 20. See Chapters II and III. The camel was known in Palestine before the time of David, c. 1000 B.C. V. 1 Samuel xv. 3.—*Editor.*

The Riding Camel is merely a lighter type, which has been bred for speed at the expense of weight-carrying capacity and staying power. In its most typical form it is bred almost exclusively in the north-east corner of the country, between the Nile and the Red Sea. Two breeds are recognized, namely the Anafi and the Bishari.

The Anafi is the riding camel in its extreme form. Light in body (also usually in colour), leggy, and with small hump, it is the cameline

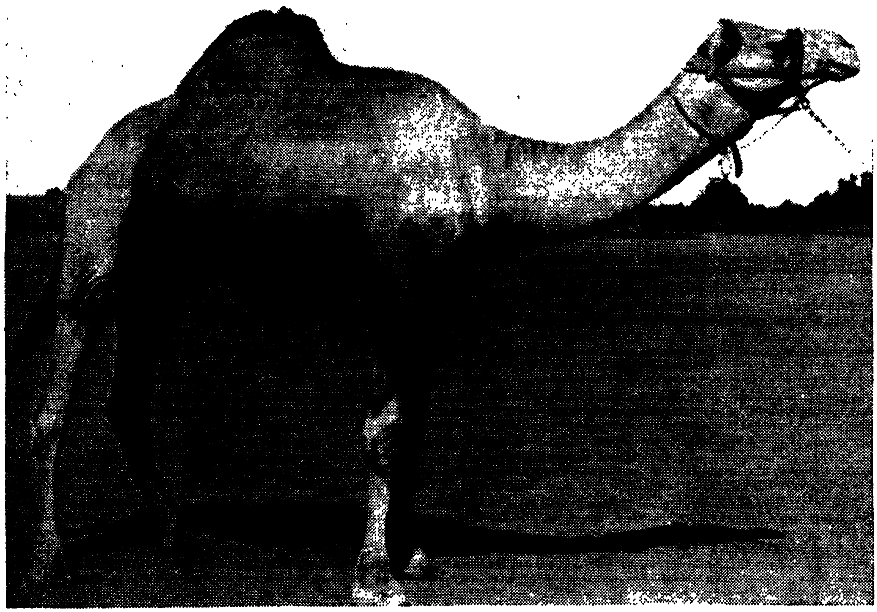

FIG. 267. Baggage camel, male.

equivalent of the 5-furlong sprinter among horses. Judged by native standards, it is the best camel in the country because it is the fastest, but weight-carrying capacity and staying power have been so sacrificed to speed that the European of medium weight finds it a rather unsatisfactory mount.

The Bishari is a slightly stronger and sturdier camel than the above. It is not so fast under light weights over short distances, but it is a better general-purpose mount. It is the breed preferred for mounted police and similar work.

V. Horses

Horse-breeding is limited to two relatively small areas in the Sudan, namely along the banks of the Nile north of Khartoum, and in southern Darfur with an extension into southern Kordofan. Each of these areas produces a distinctive type of horse, usually known as the Dongolawi and the Kordofani respectively. The total number in both areas is probably less than 25,000, and at least four-fifths of these are in the west.

The Dongolawi is considered to have been the earlier arrival, and to have reached its present habitat from Egypt in dynastic times.[1] Its only good characteristic is that it is a large horse, standing as much as 15·2 hands. Otherwise it is a clumsy animal, possessing almost every known fault of conformation. It has a heavy roman-nosed head, short thick neck, straight shoulders and pasterns, flat sides, narrow weak loins, and goose-rumped hindquarters. In colour, however, it is striking, being of a deep

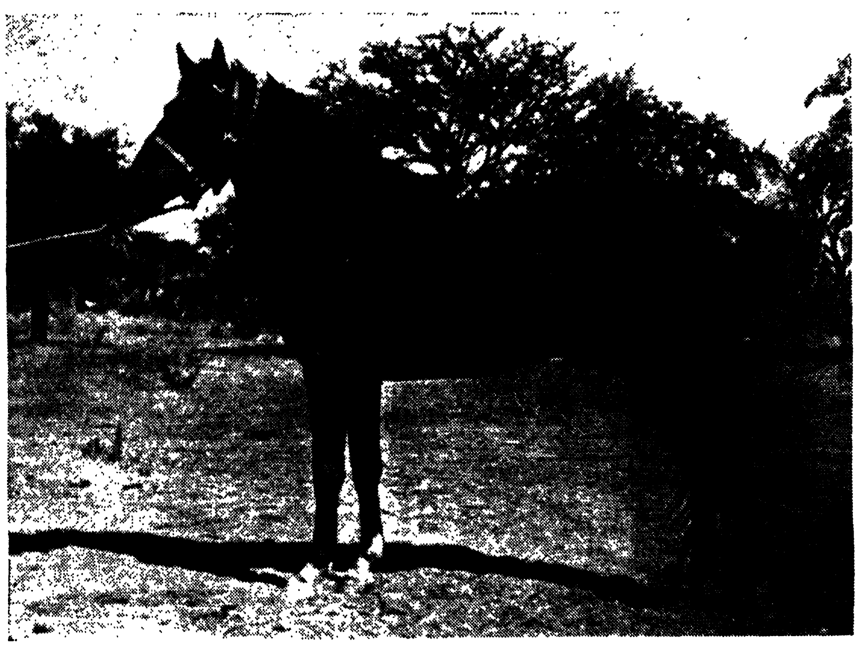

FIG. 268. Darfur (Beni Helba) tribal stallion.

reddish bay; the natives prefer specimens with a white face and four white legs. In constitution it is soft. In fact, the Dongolawi horse can be summed up as large, flashy, ugly, and useless. Its originally small, and now rapidly diminishing, numbers are no cause for regret.

The Kordofani is not happily named, because its main home is Darfur. It seems to have acquired its present designation in the early years of this century, before Darfur was reincorporated in the Sudan. It is generally thought that it originally came to the Sudan from the north-west, probably as recently as the Middle Ages.

It is a much smaller horse than the Dongolawi, rarely exceeding 14 hands in height, and is of infinitely better type, although it is by no means without faults. It is generally admitted that a fair amount of improvement resulted from admixture of blood from the imported horses (probably all stallions of Egyptian origin) captured at the defeat of General Hicks's

[1] There is general agreement that the horse reached Egypt with the Hyksos invasion not earlier than 1780 B.C.—*Editor.*

army in 1882. Generally speaking, the Kordofani is a sturdy, square-built little horse, whose faults may be summed up by describing him as 'common'. From a riding point of view a tendency to shortness of neck and straightness of shoulders and pasterns is against him, but he is capable of great endurance under hard conditions, and even the most unattractive specimens make first-class pack ponies.

The commonest colour is bay of a different tone and lighter tint than that of the Dongolawi. Chestnuts are also common, and there are a few greys. On moving westwards into Darfur, white particolouring becomes

FIG. 269. Darfur tribal stallion of improved breed.

progressively more evident, roans, skewbalds, and horses with white faces and wall-eyes being quite common.

Although not quite up to the standard required for mounting Government officials, police, or mounted military units, the Kordofani was early recognized as a type in which it was worth while attempting improvement. Stallions were sporadically imported and used from about 1910 onwards, but it was not until 1925 that any serious co-ordinated effort at improvement was made.

The horse-breeding scheme instituted in 1925 has been in operation ever since. The principle adopted was the obvious one of using imported stallions on the best native mares, and drawing on the progeny to fulfil the requirements of the Sudan Defence Force, the police, and Government officials generally. In the earlier years of the scheme English thoroughbred and Arab stallions were used in roughly equal numbers, but a few years' experience showed that foals with admixture of English blood were less likely to reach maturity than Arab crosses, and, moreover, those which did survive to working age were not so suitable for the kind of work required of them. More recently, therefore, thoroughbred stallions dying

or becoming unserviceable have been replaced either by Arabs or by selected country-breds, preferably Arab crosses, produced by the scheme. This latter policy has made it possible, in the last few years, to satisfy all official demands for a reasonably good type of working horse. Unimproved specimens, or those not improved up to the official standard, are still, as they always were, adequate for the less exacting requirements of general horse transport.

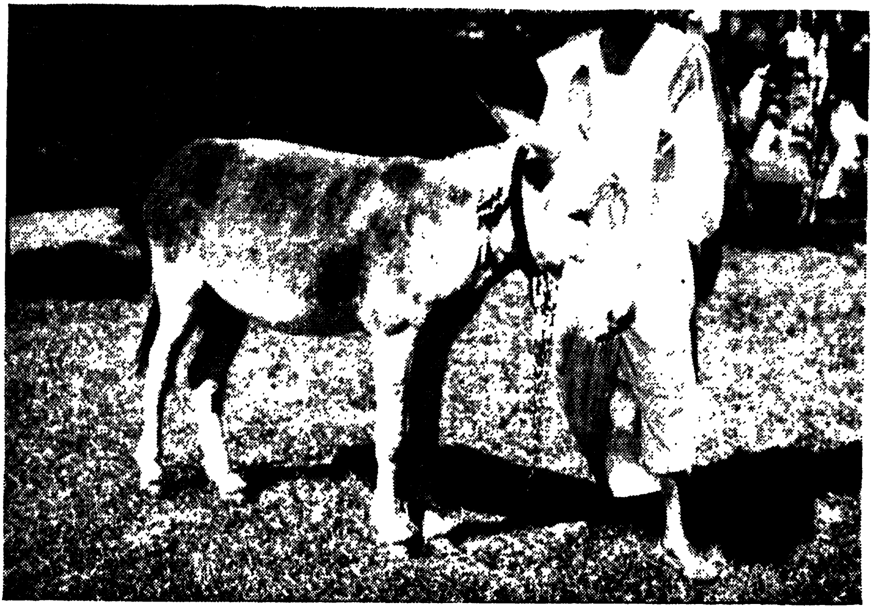

FIG. 270. Male donkey, baggage type.

VI. DONKEYS

The donkey is the transport animal of choice in the Sudan, and is used wherever it can be used. Its northern limit, away from the Nile, is determined only by water-supplies, since it cannot, like the camel, go for days without water. In the south its limit is the soil that does not become too muddy in the rainy season. About 375,000 adult donkeys are listed for purposes of taxation, and this number includes most of them. The total number, therefore, is probably somewhat short of half a million.

The only reasonable classification of indigenous donkeys is into pack and riding types, with the latter subdivided into those having or not having some admixture of imported Egyptian blood.[1]

The Pack Donkey (Fig. 270), or common donkey of the country, constitutes probably 90 per cent. of the total. It is a small, slaty-grey animal, usually between 9 and 10 hands in height, and often weedy and misshapen. A very

[1] The donkey is known from the tombs of Egypt prior to 3400 B.C. and its domestication in Egypt antedates that of the camel by something like 3000, years. Its wild ancestor still occurs in the Sudan. See Lucas's account in Chapter III.—*Editor.*

common fault is turned-out hind feet and turned-in hocks, leading to severe rubbing of the hocks when loaded. However, the average native considers that one working donkey is as good as another, and replacements are easy and cheap, so no form of improvement or selection ever enters his mind. In spite of its unpromising appearance, the pack donkey has astounding strength and endurance. When engaged in official transport duties, 100–150 lb. is the load allotted to good, specially selected, individuals, but many a miserable specimen belonging to a private owner has regularly to

FIG. 271. Male donkey, riding type.

carry 200-300 lb. Having staggered several miles to a market town under such a load in the morning, the contrast of merely having to carry the owner—and possibly also another member of the owner's family—back to the village in the afternoon is so great that the animal will return to home at quite a smart amble.

The Riding Donkey (Fig. 271) has been derived from the pack type by selective breeding. It is larger than its prototype, standing from 10 to 11 hands, and, as a certain amount of care has been exercised in its breeding, it is more likely to have a fairly straight action. Many specimens tend to be dark brown, rather than grey, but no effort is made to breed for any particular colour. This type of donkey is a wellnigh tireless mount.

In addition to the above truly indigenous types, there are a few large white donkeys standing as high as 12 hands or more. These, however, are wholly or mainly Egyptian. They are very strong and fast, but lack the endurance and hardiness of those of pure Sudan blood.

THE ROLE OF ANIMALS IN RURAL LIFE IN THE SUDAN

The animal owners of the Sudan fall into three main groups, the nomad Arab tribes of the north and west, the Nilotics of the south, and the riverain peoples who live along the banks of the Nile between the 13th parallel of latitude and the Egyptian frontier.

The nomads range over nearly all the remote districts of northern Sudan. Their habitat is sparsely populated and they follow their flocks and herds over vast areas in search of grazing and water.

The people's whole mode of life is bound up with the well-being of their livestock, and it is upon the animals that they depend for their subsistence. The milk of cows, camels, sheep, and goats forms one of the most important parts of their diet, their tents and rugs are made from camel-hair, and their saddlery, harness, and ropes from hides. And, while the nomadic life they live is dictated by the needs of their herds, it is only made possible by employing their animals as beasts of burden. The Baggara of Kordofan and Darfur load their women, children, tents, and all the impedimenta of camp life on the backs of their cattle, just as other tribes use their camels.

Normally these people do not eat meat except when ceremonial occasions provide excuses for slaughtering animals, but the tribal customs and religious calendar of the nomads are happily so ordered that such excuses occur frequently.

The most recent tribe to emigrate into the Sudan from Arabia, the Rashaida, carry on an extensive trade across the northern frontier, sending large herds of camels on the hoof to upper Egypt, where they are sold for meat.

Livestock, however, play no part in such agriculture as the Arabs practise; their strength is not used to till the soil, nor their manure to enrich it. In fact it is no exaggeration to say that most of the cattle-owning tribes regard cultivating as unpleasant, degrading work, which within living memory was performed by slaves bought with the wealth derived from their cattle.

The Nilotic cattle men occupy the river swamps of the upper Nile.

These long-legged pagans ('The Gentle Savage' of Wyndham) live in even closer association with their cattle than do the Arab nomads, for climatic conditions and beasts of prey necessitate a more highly organized mode of life and system of stockmanship. While the Arabs assess their wealth by the size of their herds, the Dinka, Nuer, and Shilluk attach a much more individual importance to their cattle: they know them all by name, and litigation concerning their ownership is one of the most popular Dinka recreations.

As a result of living in such close contact with their cattle, their animals have come to assume an almost religious significance with them. Every self-respecting young man possesses a special bullock in which his personality is alleged to be symbolized: these animals are specially fed and groomed, their horns are trained and decorated with tassels, they are lauded in song and regarded with an affection almost amounting to worship.

During the dry months the livestock, accompanied by the young people of the tribes, live in cattle camps on the low-lying pastures that are inundated when the rivers are in flood. At the onset of the rains they return to the villages on the higher land where they graze by day, and at night are either housed in large circular byres or tethered closely together down wind of dung fires, the smoke of which affords some protection from the swarms of blood-sucking insects.

All the cultivating is done during the period when the cattle are at home. The most widely grown crop is millet; it is the staple diet of the people and provides them with the beer of which they are so fond.

The Dinka of Aweil district rank among the best rain cultivation farmers of the Sudan. Their cultivable land is too densely populated to permit shifting cultivation in its most extravagant form and consequently a system of farming has been evolved which maintains the soil in fertility for long periods without recourse to resting.

One of the most interesting features of this agriculture is the intelligent use made of cattle manure. Before the annual move to the cattle camps the herds are tethered at night over the land intended for the coming millet crop. The tether pegs are spaced about 2 metres square apart, thus each animal covers approximately one-thousandth of a feddan at every stand. The stance is changed every fourth night, so the soil receives a liberal dose of manure, to which it responds with greatly increased crops.[1]

The manner in which Dinkas enhance their personal appearance with animal produce is also worthy of mention. The complicated patterns of grey smears on their bodies are obtained by the application of ashes from cow-dung fires, and the hair tonic which enables them to cultivate such attractive yellow coiffures is unadulterated cow urine. The writer once met a Dinka brave soon after his discharge from hospital, and inquired as to his health. The man replied, as he patted his head adroitly, 'Oh! I'm much better in myself, but my hair has got into an awful mess while I've been laid up'.

In the two groups discussed above, livestock are the be-all and end-all of life, they represent the sole wealth of a people whose main occupation is stock raising.

Along the river, however, animals play only a contributory part in the rural economy. The chief means of livelihood is agriculture, and cattle are regarded as necessary accessories to crop production.

From time immemorial their chief role has been that of driving the 'sāqiya' wheels which lift water for irrigation. This type of farming dates back to about 300 B.C. when the 'sāqiya' was introduced to Meroe and is still the mainstay of the dwellers along the Dongola reach of the Nile.

It has been said that an efficient 'sāqiya' is a machine capable of watering almost enough land to provide fodder for the animals that drive it. Be that as it may, for nearly two thousand years 'sāqiya' cultivation has supported the people and their animals and has maintained the soil in a high state of fertility. Ages back it evolved an economic equilibrium which it has taken the repercussions of two world wars to disrupt.

[1] For further references from other points of view see pages 294 and 694. —*Editor.*

In recent years the increasing population has caused minute subdivision of their 'sāqiya' lands and poverty due to land hunger has begun to make its appearance.[1] In Dongola this has driven many of the men far afield in search of work, but the 'sāqiya' lands of their forebears still remain the home of their womenfolk, the breeding-ground of their families, and the haven of their old age.

Farther south the flight from the land has been less marked, but the same motive is resulting in the adoption of a more modern and less

FIG. 272. The 'Walley' yoke. This is now in universal use in the northern Sudan wherever cattle are used for ploughing.

laborious method of irrigation: mechanical pumps are gradually replacing the old water-wheels. Here, although cattle are playing a declining role in water lifting, their numbers show no signs of decreasing, for the bulls and cows that formerly turned the water wheels are now employed to plough the land which they previously watered.

It is satisfactory to note that the people that have been the first to change from animal to mechanical power for their pumps have also been the first to adopt animal cultivation. In Merowe–Dongola district, where the 'sāqiya' are fighting their most stubborn battle against extinction. ploughing is the exception rather than the rule: in Berber Area and on the White Nile, cultivation by bull-drawn implements is rapidly becoming standard practice.

It is by their contribution to soil fertility, however, and as producers of milk that cattle are likely to play their most important part in riverain agriculture in future. 'Sāqiya' may give way to pumps, working bulls may conceivably be replaced by tractors, but animals will still be required to

[1] For further discussion of land fractionation see Chapter XII.—*Editor.*

keep the land in good heart. The manure they produce is invaluable, but probably even more important is the fact that the fodder crops grown to support them are mainly leguminous, *Dolichos lablab* L. being the most widely grown and the most valuable.

It is on the inclusion of such legumes in the rotation that the soil depends for its fertility, and no system of farming in these crowded areas that does not make ample provision for these crops is likely to enjoy permanent prosperity.

So long therefore as the narrow strip of cultivable land along the Nile is required to support a dense rural population, the role of cattle is not likely to diminish.

DAIRY FARMING

The Sudan is not a particularly suitable country for large-scale dairy farming except, possibly, in those districts where irrigated agriculture is practised and herds can be properly fed throughout the year. Under rain conditions milk production in quantity is restricted to a very limited season of the year, and in any case the heavy machinery required for dealing with large quantities of milk cannot be moved about with cattle migrations.

Considerable scope does, however, exist and little as yet has been done to provide an adequate supply of good quality milk to satisfy the needs of the population of the towns and larger villages. The question of milk supply is closely connected with that of soil erosion and the periphery control of towns and villages. Milk is probably the most essential of all foods to the Sudan native, and if it is made available to him cheaply and in adequate supply, it is not unreasonable to assume that there will be a steady reduction in the number of goats kept by him with a proportionate improvement in the quantity and quality of the local vegetation, especially that immediately adjacent to a town or village. As it is most important that a level supply should be maintained throughout the year, its source will have to be based on agriculture which is productive for twelve months in the year, that is to say, cultivation by irrigation. It is only from an artificially irrigated area that an abundant supply of green food, so essential for the maintenance of a dairy herd, will be forthcoming.

It is the practice in the Sudan for those who are able to possess their own milk animal, and as long as this arrangement remains possible and moderately economic, there is little chance of dairy farming for local consumption becoming a thriving industry. The few dairies now existent owe their inception to the demand which always exists in a British community, wherever it may be, for a good supply of clean milk. Khartoum itself is well served by the old-established Belgravia Dairy owned by Messrs. Kfouri, and Government herds exist amongst other places at Wad Medani, Port Sudan, and Juba.

The Belgravia Dairy, which was founded by the Veterinary Department about 1907, passed into private ownership in 1932, since when it has been considerably enlarged. At present the herd consists of some 320 head, of which about 160 cows are in milk at any one time. Most of the stock is cross-bred Friesian-Native. Extremely good yields have been recorded,

individual cows having produced as much as 1,300 gallons in a lactation. A large milk round is maintained in the three towns, and almost all the daily production of 250 gallons is disposed of by house-to-house delivery from special vans.

At the Gezira Research Farm, Wad Medani, where a small herd of Kenana cattle has recently been established with a view to improving the breed, very satisfactory milk yields have been recorded. The average daily production per head for the 20 to 30 cows in milk remains steady for the greater part of the year at between 15 and 20 lb., whilst a maximum

FIG. 273. The Gezira Research Farm herd of dual-purpose, Kenana-type, cattle for production of milk and working oxen. Note the dewlap, the horns, the hump, the gentle slope from hip-bones to base of tail, and deep forequarters. The colour is grey. Stock bull 'Baba'.

individual yield of 37 lb. per day and over 7,000 lb. per lactation of 10 months has been obtained. Cows have been sent from this herd to establish one at Port Sudan, where under very different conditions they have continued to give satisfaction. The scope of this newly established Port Sudan herd, however, will always be limited by the local scarcity and consequent costliness of fodder and water.

The herd of Dinka cattle maintained at Juba is a great boon to the local European population, although the proposition economically is an unsatisfactory one, as the cows of this breed are such poor milkers.

Attempts have been made during the past year to produce locally a substantial proportion of the country's fresh butter requirements. A scheme capable of a butter output of 1,000 lb. per month has been started at Shendi, where a dairy farm has been temporarily established on the assumption that it would be transferred to a permanent site in the Atbara neighbourhood as soon as circumstances permit.[1] The animals for this herd, which were obtained in the Abu Deleig district of the Butana from the Shukria and Batahin tribes, are of a type admirably suited to

[1] This has since been done.—*Editor.*

conditions of riverain agriculture. It is intended eventually to retain only the best of these animals for the foundation of a herd which will be improved by selective breeding and good management, and from which the best stock will be available for distribution. It is hoped to make the scheme self-supporting by the sale of whole milk, &c., in Atbara.

A small dairy has recently been established at Erkowit. The cows remain the property of the local Arabs who bring them daily to the Rest Camp cow-house and milk them under the close supervision of a trained supervisor.

Native cows will not normally let down their milk except in the presence of their calves, which means that if the calf should die its mother will most

FIG. 274. Gezira cattle. A dual-purpose breed of Zebu extraction. Kenana type.

probably 'dry-off' at once.[1] The practices of skinning and stuffing the calf and producing it at milking time, and also of inflating the uterus immediately prior to milking are popular, but they can hardly be described as successful. The presence of the calf at milking does tend to produce unhygienic conditions, but it is generally a case of choosing between this and no milk at all. It is asserted by many cattle owners that if a heifer's first calf is removed at birth and she is not permitted to suckle it, she will acquire the habit of milking without her offspring during this and all subsequent lactations.

This, of course, means that calves will have to be hand reared, and it is extremely rare in the Sudan to find a calf being brought up 'on the bucket'. The common and, in fact, the only method in common practice is for it to be permitted to suckle its mother and obtain what remains in her udder after her owner has satisfied his requirements. For this reason it is usual to find calves very poorly developed for their age in spite of the fact that the 'strippings' are usually the richest of the milk. There is always a period immediately following the drying-off of the cow when the calf loses much of its condition, and it is several months before it again begins to thrive.

[1] In the School of Agriculture herd at Shambat the cows have grown accustomed to letting down their milk without their calves being present. It seems to be a matter of early training.—*Editor.*

Only in recent years has any attempt been made to improve the milking capacity of local stock by culling inferior animals and breeding from the best. As yet this selection is restricted solely to the males, and even here the numbers castrated or disposed of are small, although during the past 2 years the greatly increased demand for bulls and bullocks for export to Egypt has accelerated matters. On properly administered schemes a stock bull of good type and ancestry is usually kept.

Considerable difficulty has always been experienced in arranging a calving programme to ensure that the supply of milk does not fluctuate

FIG. 275. A Gezira cow and calf. A dual-purpose animal for milk production and for working oxen. Zebu extraction.

with the various seasons. At the Research Farm in Wad Medani where a bull is allowed to run with the herd during grazing hours, it has been found that individual cows, almost without exception, calve down regularly each year at the same season. The number of animals calving down is much greater during some months than others, and it has been found that a cow will tend always to calve down at the same season as that at which she commenced her breeding career, and in most cases defy all efforts made to change her season of parturition. The purchase of young cows which have already calved at the required time or an attempt to influence the date at which heifers are first mated would seem to be the surest way of providing for a regular and constant supply of milk throughout the year.

Unfortunately, local custom expects a cow to thrive and produce milk on what food she can pick up whilst out grazing, which is more often than not insufficient to maintain condition. Although a certain amount of supplementary feeding is done in those milk-producing herds which are managed on more up-to-date lines, it is unusual to find owners sufficiently far-sighted to feed stored fodder, silage, dura, or cake to their animals. In

cases where it has been done the yield of milk has increased to a degree which more than compensated for the cost of the extra food consumed. A daily ration of a mixture of 5 lb. of crushed dura and 3 lb. of cotton or sesame seed cake or meal, fed in two equal parts, during the morning and afternoon milkings has produced yield increases of from 20 to 40 per cent.

In a few of the better managed milk-producing schemes records have been carefully kept for a number of years, and it is now possible to give some indication of yields. With adequate feeding a good native cow of the Kenana or Shukria breeds will produce from 250 to 400 gallons during a lactation of 8 months. Any yields over 400 gallons per lactation are exceptional, although some animals at the Research Farm have exceeded 500 gallons, whilst at least half the herd have at some time or other given for weeks on end a daily average in excess of 2½ gallons. The milk of the Sudan cow is of good quality, and normally contains more than 4 per cent. butter fat.

The buildings necessary for dairy farming in the Sudan are of the simplest. Little more is required for a milking shed than that it should have a concrete floor and a sun-proof roof. The dairy itself should be in as cool a position as possible, well ventilated and fly-proof.

Although the cow is looked upon as the milk animal *par excellence*, large sections of the community must always depend for their milk supply upon the camel, sheep, and goat, each of which has characteristics which make it peculiarly suited to certain districts and conditions. The Sudan camel is said to be capable of producing up to 2 gallons per day, whilst yields of 3 and 6 pints per day respectively are not uncommon from milk strains of well fed sheep and goats. The subject of providing milk supplies for the poorer people of towns and villages and of the erosion problem that is involved in the provision of fodder for sheep and goats in peripheral areas is dealt with at length in the report of the Soil Conservation Committee published in 1944.

BEEF AND MUTTON

The Sudan has it in common with all essentially pastoral countries that butcher's meat constitutes a small fraction of the regular human diet. Animals, indeed, are numerous, but they represent the wealth, and not the food, of the people. Nevertheless a fair amount of meat is eaten, if not in the form of regular meals. In the purely pastoral areas, both in the north and in the south, there are numerous social functions and ceremonies at which it is customary to slaughter and eat sheep, and sometimes even cattle, while in the south any animal that dies, from whatever cause, is also regularly eaten. Thus, although the inclusion of meat in the diet is either ceremonial or purely incidental, the total amount consumed is by no means negligible. In parts of the south, indeed, the natives probably eat as much meat, although irregularly and not under very aesthetic conditions, as they would do if butchering were a normal practice.

The internal demand for meat is, however, only to be estimated with any pretence to accuracy in urban areas. Pastoral peoples, although they are very reluctant to part with their animals, are not entirely self-sufficient,

and must have cash with which to buy the luxuries of life and to pay their taxes. The cash income derived from selling hides, clarified butter, and various catch-crops is hardly sufficient for their needs, so that livestock have to be marketed to make up the deficiency. There is thus no shortage of meat in urban centres. Records of slaughterings are not kept in all butchering centres, but in ten 'large towns' that have for several years been regarded as indicators, about 2,000 camels, 20,000 cattle, and 200,000 sheep and goats (mainly sheep) are annually slaughtered, fluctuating upwards and downwards with the standard of general prosperity. These figures represent probably 75 per cent. of regular abattoir slaughterings, since all other centres are much smaller than the few in which records are kept. The popularity of the different classes of meat is in proportion rather to the number of animals of each species slaughtered than to the total weight of each class. Few people, in fact, will eat the local beef if they can afford mutton, which is about one-third higher in price.

Goat meat is not an article that finds much sale in the retail market, but this is not on account of any inherent objection to it, although the flesh of *old* goats is considered rather too highly flavoured. The goat is primarily a milk producer, and in order to conserve milk supplies most male kids are usually slaughtered and consumed domestically at a very early age. It is, moreover, the custom to keep nannies in milk until they die of sheer decrepitude, so that the opportunities for goat flesh to appear on the butcher's counter are strictly limited. For those whose taste inclines toward goat meat, it is said that Zaghawi mutton is a passable substitute.

Although, in normal times, most cattle and sheep sold for slaughter are destined for the internal market, a certain number are also regularly exported to Egypt. Beef is the meat of choice in Egypt, and the country is unable to fulfil its own requirements thereof. The Sudan is not, however, called upon to any great extent to supply the deficiency, and for this there are at least two good reasons. The first is that the type of beast almost exclusively exported is the Arab zebu, and zebu meat cannot compete with that of the domestic ox.[1] The second reason is that cattle are exported straight off pasture, and are therefore not always in first-class butchering condition. A month or two after the rains are well established, say in August, they are, indeed, in very good condition, but from the end of October they gradually fall away until, by about the end of April, they are frankly unfit to export. In normal times, in fact, export is usually suspended in May, June, and July. Efforts to bridge this gap with southern cattle, which always yield a better quality of beef, and are at that time of the year in good condition, have hitherto failed, partly because southern cattle are of a 'soft' type and do not stand up well to the rigours of a long journey, but mainly on account of the difficulty of inducing the Nilotic tribesmen to sell sufficient numbers of cattle at economic prices.

Egypt, moreover, ordinarily has alternative sources of supplementary supply, namely the Balkan countries, which produce large cattle of good

[1] It may be more a matter of condition and butchering than of breed. I have tasted excellent beef in Uganda produced from zebu cattle when in really good condition and properly butchered. The Afrikander cattle of S. Africa which have a good deal of zebu blood also produce good beef.—*Editor.*

type at economic prices. Thus, since the demands of non-Muslim residents are largely satisfied by imported chilled or frozen beef, and since the better class of Egyptian consumer can pay for a superior quality of the locally slaughtered article, the only basis on which Sudan beef can compete, in normal circumstances, is that of cheapness. Its usual destination is, therefore, certain holders of public contracts, who need not supply their clients with the best beef, and the poorer class of private consumer who cannot afford anything better.

Sudan mutton, obtained from Desert sheep, is probably in no way inferior to the home-grown Egyptian article, but mutton is not the popular meat of the urban centres of Egypt, and the last few years have seen the country satisfying a progressively larger proportion of its normal demands.

As an indication of the low popularity of Sudan beef, and the small requirement of imported mutton in Egypt, the numbers of cattle and sheep exported in 1938 (the last full pre-war year) may be quoted. Only 7,256 cattle and 1,840 sheep were exported.

A branch of the export meat trade that is apt to be overlooked is that of camels. These are not transported by rail and river, as in the case of cattle and sheep, but are driven in large herds by road to markets in upper Egypt. Since they do not pass through recognized customs stations, but travel by certain desert routes specified in special export permits, records of them do not appear in trade reports. A few working camels are included, but the great majority are fat barren females whose destination is the butcher's shop. The average annual total so exported is about 20,000.

With the advent of the war the Egyptian demand for cattle and sheep has greatly risen, since the meat-eating population has increased while alternative sources of supply have been reduced. What the ultimate demand may be is unknown, but it is known that in 1918, the last year of the First World War, nearly 40,000 cattle and over 200,000 sheep were sent to Egypt, although in those days the control of animal diseases was in a very rudimentary state compared with the present time. It therefore seems that if all demands from Egypt cannot be met, the limiting factor is likely to be something other than the unavailability of sufficient healthy animals.

CLARIFIED BUTTER

Clarified butter (Ar. 'samn' or 'masli') is the one animal product to the making of which the pastoral nomads of the Sudan apply any regular effort. Many thousands of tons are annually prepared, some of which is stored by the makers for their own use, while the surplus is sold. Most of what is sold is consumed in non-pastoral areas within the Sudan, but a national surplus of several hundred tons is annually available for export; this goes mainly to Egypt. A large proportion is of poor quality, being rancid and dirty. Although rancidity does not detract from the actual nutritional value of the article, it renders it decidedly unattractive to palates which have acquired a taste for something better, and, generally speaking, only the best local grades are fit to export.

The main feature of local production that is responsible for the low

average quality, i.e. high average rancidity, is that manufacture is carried out on a strictly family basis. Each family churns its own surplus of milk in a gourd or sheep-skin, and keeps its own small stock of butter until enough has accumulated to warrant the trouble of boiling it, and, since any one family produces only a small amount of butter daily, some delay is bound to occur before the accumulation is finally boiled. The quality of the final product will thus obviously be inversely proportional to the amount of delay. A second important factor making for inferior quality is that the natives do not always thoroughly boil their butter. A slightly under-boiled sample sets to a better consistency than an overboiled one, and, incidentally, weighs rather more. Traders who buy the product are, however, aware of this, and it is a common practice among them to reboil their stock to drive off the last traces of water and at least prevent it from becoming more rancid than at the time of purchase. At the same time they strain it to remove gross dirt.

Local conditions vary greatly from area to area, and these have a material influence on the quality of the final product. Roughly speaking, sets of conditions can be analysed into three groups, namely, those obtaining in the two southern provinces, the northern riverain areas, and the northern non-riverain areas respectively. The southern provinces may be dismissed by saying that for all practical purposes they do not produce clarified butter, since southern cows, with extremely rare exceptions, yield so little milk that there is no surplus available for the purpose. In the Arab areas of the north production is mainly seasonal, because there is a single well-defined rainy season during which nearly all cows calve, and it is only at this season, roughly the four months July–October inclusive, that there is a surplus of milk.

The difference in the quality of clarified butter produced in non-riverain and riverain areas depends partly on grazing and watering conditions and partly on market facilities. In non-riverain areas the cows have more leeway to make up after the dry season and do not, on an average, give quite so much milk. The number of cattle owned by any one family is also, on the whole, somewhat smaller. The Arabs of the hinterland are thus in the habit of storing butter for a longer period than the riverain tribes before boiling it down. In respect of marketing facilities the riverain folk are also at an advantage, since marketing centres are more numerous and more easily accessible than in the hinterland. It thus arises that clarified butter made in riverain areas is less rancid at the outset, and is also reboiled by the traders after a shorter period of storage, than that prepared in non-riverain areas. Nevertheless, the riverain product is not constantly of good quality, and even the aromatic seeds that are frequently added fail to disguise its rancidity. Riverain 'samn' is, indeed, the best, and, although it constitutes but a small fraction of the total thrown on the market, it accounts for the bulk of what is exported. In Egypt, however, it realizes from 25 to 50 per cent. less than its Egyptian counterpart.

Attempts have recently been made to introduce the 'direct' method of preparation, i.e. to eliminate the butter-making stage and to boil down mechanically separated cream that has either been washed or allowed to sour by standing for 24 hours. Both variations of this method have been

operated with considerable success in other territories, but conditions in the Sudan are not so favourable, and scope for the 'direct' method is more limited.

The main limiting factor is a scanty seasonal rainfall which enforces a nomadic existence on all pastoral tribes, since any given grazing area either will not maintain a heavy concentration of cattle or, if large numbers exist, will only support them for a short time. Even the areas of the greatest cattle concentration are sparsely stocked as compared with almost any other country. Since it is only in these areas that centralized clarified butter manufacture is at all practicable, and these areas may not be the same every season, nothing more than temporary mobile outfits can be employed. The impracticability of erecting permanent buildings entails the sacrifice of certain refinements of technique. Probably the most serious drawback to not having permanent buildings is that with the necessity for using poor quality or damp wood as fuel, which often cannot be avoided, the boiling cream may become tainted with smoke, this fault being almost as objectionable to the high-class consumer as rancidity. Only six mobile creameries, worked under official supervision, have so far been put into operation in selected areas, and none of these has yet produced a quantity of clarified butter that in other countries would be considered the minimum that would justify the maintenance of a creamery. Greater capital expenditure is therefore not warranted.

The human factor is also unfavourable to much improvement. As an example, one area may be quoted where an Animal Husbandry Officer spent a whole season training local tribal staff who, under his supervision, prepared a fairly good article. The following season, when the instructor had moved to another area, the output of the first centre was unmarketable. Furthermore, the exporting merchants have shown no interest in the 'direct' method article. It costs them slightly more to buy, since it cannot be prepared so cheaply as native 'samn', on which nothing is expended by the producer but his wife's time, and the total amount produced is, and will continue to be, so small that the trouble of finding a separate market for it is not worth while. Very few Sudanese will buy it, even if they can appreciate it and afford it, because they are accustomed to the native product, and do not think the improved article is worth the slightly higher cost. The only market envisaged for it is, therefore, the European community within the country, who will buy it so long as it remains cheaper than butter or than imported margarine and similar articles.

DRIED MEAT

Dried meat has always been an important item of diet in the Sudan, and a certain amount has always been exported to Egypt. As in the case of fresh meat, however, it is the internal market that is the more important.

In the northern Sudan a very large proportion of the fresh beef purchased from butchers' shops in towns is dried. Camel meat is also sometimes dried, but mutton never. In northern pastoral areas the drying of

beef is practised in slightly different circumstances. No pastoral Arab kills a bullock merely for food, but there are numerous ceremonies, e.g. weddings and circumcisions, at which cattle are slaughtered for consumption by the guests. Lavish display is expected, and there is thus apt to be a surplus of meat over actual requirements; this is subsequently dried.

In the pagan pastoral areas of the south meat is also dried as a preservative measure. Here, however, it is not only the surplus meat from feasts that is dried, but spoils of the chase and the flesh of any animal found dead are also included. No meat comes amiss to the southerner, whether fish, flesh, fowl, or good ripe reptile.

When drying is practised simply as a measure of domestic economy, as in the circumstances mentioned above, the meat is cut into long strips about an inch thick and hung up, either in the sun or shade, to dry. In pastoral areas it has to be taken down at night in order that wild animals may not steal it, and once taken down it may not be hung up again but merely spread on grass mats to complete its drying out. It seems that, if drying for the first few hours is properly carried out, there is little danger of putrefaction if less care is devoted to the later stages. Complete drying may take a week or more, according to the weather. In Arab areas it is only the red meat that is dried, since the viscera, being special delicacies, are among the first portions eaten. In fact they are usually eaten raw, chopped up and sprinkled with fresh bile to give them an added zest (Ar. 'mirrara'). In the south, however, any and every tissue is dried.

Dried meat (Ar. 'sharmūt'), as prepared in Arab areas, is very wholesome and palatable, although its appearance is not attractive. Its main drawback is that if stored for any considerable period it is almost certain to become infested with beetles. It will, however, remain free from putrefaction almost indefinitely. It certainly is in every way suitable for the purpose to which it is put, namely, storage for short periods and ultimate incorporation in soups and stews.

Dried meat that is destined for anything but fairly early domestic use must be salted, and in the Sudan one of two salting techniques is employed, depending on whether the meat is intended for export to Egypt or for home consumption.

Salted dried beef has been regularly exported to Egypt ever since the Anglo-Egyptian reoccupation. The meat is cut into thick slabs, rubbed on the surface with salt, and dried for a few days until a hard salty shell forms on the outside. It is then immediately exported, and reaches the consumer in a few more days. This type of dried beef (Ar. 'bastūrma') will not keep for more than a week or two, especially if it is roughly handled in transit so that the outer shell becomes broken, but if there are no delays *en route* it is a useful and cheap form of meat.

Salted meat has not been much used within the Sudan, doubtless because there has, until very recently, been no demand for dried meat whose requirements the cheaper 'sharmūt' would not satisfy. During the course of recent military operations, however, circumstances have arisen in which considerable bodies of Sudanese troops could not be regularly supplied with any other form of meat. Stocks of plain dried 'sharmūt' could not be held, owing to the liability of infestation by beetles. It was also

soon found that the mere rubbing in of salt and hanging up to dry was equally unsatisfactory, even though the meat was cut into very thin strips and thoroughly dried out. As in the case of 'bastūrma', the outer salty shell became broken in transit, and stocks held for any length of time became heavily infested with beetles. The only technique that has proved satisfactory is to cut meat into thin strips, pack with powdered salt in tanks and leave overnight, and finally hang up to dry. Meat prepared by this method has not yet become an article of civilian diet to any significant extent, but it is conceivable that if it can be prepared cheaply enough it may in time become popular in a few areas of the south, where the presence of tsetse-flies precludes the keeping of domestic stock.

HIDES AND SKINS

The economic difference between hides and skins is that the main importance of hides lies in their value as exports, whereas skins are very extensively used within the country. In the case of the two southern provinces, indeed, it is hardly an exaggeration to say that not a single sheep- or goat-skin reaches the export market. When once the export stage has been reached, the difference between the two articles is that Sudan sheep-skins rank very high in the world's markets, while hides rank very low.

Cattle Hides

Sudan hides are basically of poor quality, and their low original quality is aggravated by many adventitious faults. At best they lack 'body', and in addition there is usually so great a disparity in the thickness of the relatively thick and thin parts that they work up into a very uneven 'butt'.

Faults of extraneous origin are largely preventable, but there are some that cannot be avoided. Horn-rakes and thorn-scratches are inevitable in an arid pastoral country where most vegetation is thorny and animals are often herded in a small thorny 'zarība' at night. Serious though such mechanical injury is, however, it is not the most important source of unavoidable damage. The most important is the fact that the great majority of hides coming on to the market are recovered from beasts which have died of exhaustion or disease. In such circumstances the hide has already undergone some deterioration before the animal dies, and when, as is often the case, the carcass is not flayed for half a day or more after death, the hide embarks on its commercial career with a heavy handicap. There are, indeed, slaughterhouse hides which are recovered from healthy animals under ideal conditions, but, since about 90 per cent. of those coming on the market are from dead beasts, it is evident that no amount of care in flaying and curing can keep the quality above a certain low average level.

Unfortunately all due care is not taken in flaying and curing. Cattle die in all kinds of inconvenient spots, and since, for example, nobody can be expected to work in the sun if shade is near, the carcass is often dragged, and the hide badly scored, before flaying. More serious damage, however,

arises out of faulty technique in flaying and curing. Little effort is made to avoid cutting the hide, although when an awkward tool such as a spear is used, it must be difficult to achieve good results. But the most serious damage of all arises out of the common practice of pegging the hide out on the ground in order to dry it. The hide does, indeed, dry, but drying of the under side is usually delayed long enough for a fair amount of putrefaction first to occur. Also, before the hide is quite dry, because it is too difficult to handle when completely dry, it is often folded into a square packet

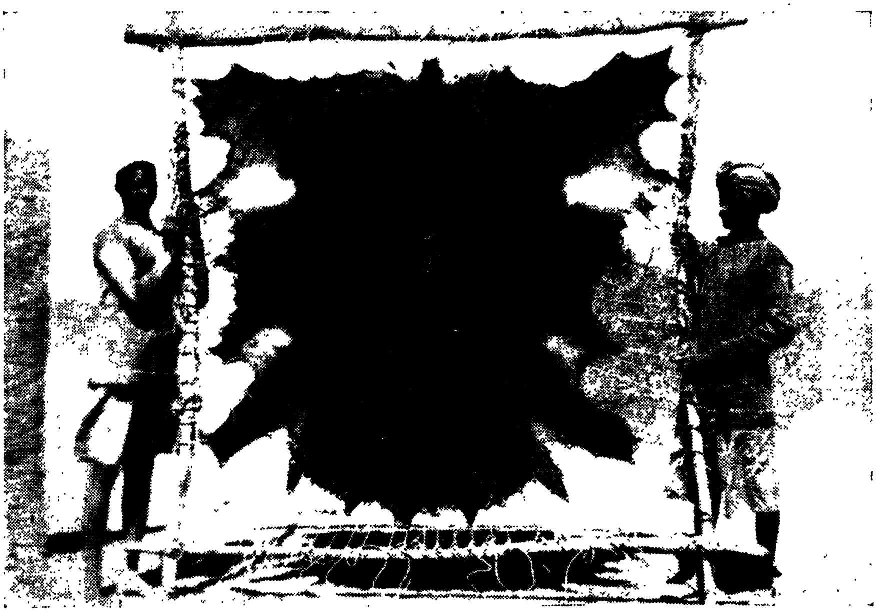

FIG. 276. Hide on frame for air-drying.

convenient for carriage on a donkey, which is the only form of transport likely to be available to the itinerant trader who will probably buy the hide.

Efforts have been made during the past 5 or 6 years to induce the pastorals to adopt a method of drying on rough wooden frames (see Fig. 276), but without much success. The reason is not a shortage of rough timber, or even inherent laziness on the part of the pastorals, but the great variability in hide prices, whereby a man who takes trouble over his curing may obtain less money on a falling market, and then see his neighbour, who takes no trouble at all, obtain more money on a rising one. It has not yet been realized that a superior article, even though it has its ups and downs, will obtain a higher average value than an inferior one.

Slaughterhouse hides are usually dry-salted, being purchased by merchants at the time of slaughter and salted on their own premises. In butchering centres at a distance from rail or river stations, however, the cost of transporting salt for hide curing is uneconomically high, and ordinary air-drying is practised.

Sheep- and Goat-skins

The basic distinguishing feature of a sheepskin destined for export is that it is dry-salted, whereas those used internally are merely air-dried. Air-dried skins are used locally, not only because it is easier merely to dry them than also to salt them, but because air-drying is preferred. A salted skin is not so suited to local tanning methods, and it is stated that in the case of water-skins—a very important article of internal commerce—no matter how long a salt-cured skin remains in use, it will impart a brackish taste to water. This is probably true, as native water-skins have not a very long life. In any case, unless very fine results are required, an air-dried skin provides as good a leather as a salted one, and a growing number of air-dried sheepskins is being exported to Egypt. All goatskins are air-dried, but relatively few come on the market.

The dry-salted skins exported are said to provide leather of the very best quality, and exporters, in order to maintain their high reputation, are careful to export only pieces that have been flayed from healthy sheep and immediately salted. Even the skins used for local tanning are of very good quality, and are at any rate flayed from slaughtered animals, since the inhibition that exists about slaughtering cattle does not apply to sheep and goats.

The Local Leather Industry

Very little leather is imported into the Sudan, since, with few exceptions, the demand for articles made of foreign leather is satisfied by manufactured leather goods. A few hides are tanned in the country, mainly for the making of soles for shoes, but the true leather of the country is sheepskin, including in this designation a small percentage of goatskins. A fair number of skins, especially those which are to be dyed or made up before retailing, are tanned on a semi-industrial scale in a few of the larger towns, but the great bulk of local leather is made on a 'cottage industry' scale by small village tanners, or even by the owners of the skins.

One of the most important leather articles in general use is the 'qirba' or whole-skin vessel, which is used mainly as a water container or as a churn. Skins are therefore invariably pulled off slaughtered carcasses without splitting along the belly, and stored after drying in this form. They are thus always suitable for converting into 'qirab', but if required for other purposes it is no trouble to split them. Another common article is the 'farwa' or saddle-cloth, which is tanned without removing the hair. The best 'farwa', bearing long fine wool, are imported, but the bulk of the population cannot afford these and have to be content with local hairy sheepskins. In addition to the aforementioned specific articles, innumerable types of shoes, bags, and miscellaneous leather articles, many of appreciable artistic merit, are manufactured.

Village tanning is a very primitive operation, depilation and tanning being merely stages of a single process. The skin is soaked in water to soften it and is then steeped in a dilute suspension of 'qarad' (pods of *Acacia arabica* L.). The hair is scraped off early in the steeping stage. 'Furwa' are made in much the same way except that, after softening in

water, the skin is stretched on a frame, flesh side upwards, and 'qarad' suspension rubbed into the upper side only. The finished article, after rinsing and drying, is massaged with a little sesame oil.

Tanning in the towns is practised more or less according to industrial standards. Lime is used for depilation, and for the best qualities mineral acids are used for puring; cheaper qualities are pured, or 'bated' with dog or fowl dung. All tanning, however, is carried out by the vegetable process, using sunt, *Acacia arabica* Linn., pods.

CHAPTER XXIII

ANIMAL FOODSTUFFS

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INTRODUCTION

IN any consideration of animal foodstuffs it is first essential to present a picture of the conditions under which the animals live in this vast country. Literature on the subject is unfortunately meagre and scattered; and it is hoped that the patent defects of this account will stimulate in many a desire to remedy the position.

There are two broad divisions: (*a*) the rain areas in which animal husbandry is largely determined by water-supplies; (*b*) the irrigated areas with perennial water-supplies, relatively small (0·2 per cent. of the total area of the Sudan) but with important livestock problems, in which food and not water is a limiting factor. Exceptions occur; for example, the Tokar and Gash Deltas are irrigated, but only during the seasonal spate of their rivers; again, appreciable riverain land is inundated by the flood-waters or by river control, and the resultant weeds and grasses when the water recedes are of very distinct value to cattle from neighbouring rain-land or irrigated areas.

Free range conditions are the normal. Intensive feeding is confined to a few special dairy herds, and to working animals in irrigated areas and in the large towns.

After an account of some of the prevailing conditions the various foodstuffs will be discussed in relation to the limited information available.

SOME CONDITIONS IN THE RAIN AREAS

Vegetation varies from nothing in the rainless north to the relative luxuriance, in the south-west, of the Nile–Congo divide under a rainfall of about 1,500 mm. (60 in.) per annum. No part, however, escapes a dry season during which green grasses and herbs are very scarce. In the grass woodlands of the south the tsetse-fly largely precludes the keeping of cattle; some of the conditions to the north of this belt are exemplified below.

Nomadic Grass Grazing in Kordofan and Darfur Provinces

Cattle-owning nomads inhabit the central and southern parts of Darfur, Kordofan, and the old White Nile Provinces. It is an area of plains and stabilized sand-dunes and is covered with numerous grasses, the amount of which varies with rainfall.

[1] My thanks are due to a number of colleagues, including F. W. Andrews, B. M. Boyns, A. W. Chalmers, F. Crowther, T. A. Fowler, I. A. Gillespie, and J. R. Thomson for much helpful advice and for accounts of conditions in the Gezira and in Kordofan; to the Government Analyst for some of the analyses; and to E. R. John for use of his valuable note on feeding problems.

The most common fodder grasses of the plains are probably species of *Aristida*, e.g. *A. adscensionis* Linn., *A. funiculata* Trin. and Rupr., *A. mutabilis* Trin. and Rupr., and *A. steudiliana* Trin. and Rupr. They grow in tussocks, are usually under 2 ft. in height, and have thin wiry stems and leaves. When dry these and others are collectively termed 'ghabash'; generally speaking they produce little leaf and seed, and are of a very low feeding-value.

Other very common grasses on the plains include species of *Sporobolus*, *Eragrostis*, *Brachiaria*, *Setaria* and *Chloris*, *Schoenfeldia gracilis* Kunth., and *Dactyloctenium aegyptium* Beauv. The last, with a head like a starfish, and *Setaria verticiliata* Beauv. have plenty of leaf; the *Setaria* looks as if it would make a good hay, whereas the *Dactyloctenium* is rather short. The other grasses are mostly stalk.

Found particularly on the dunes are the true and false 'haskanīt' (*Cenchrus biflorus* Roxb. and *C. ciliaris* Linn). Despite their prickly nature they are probably better fodders than many, containing more leaf and seed.

Two other most important grasses are *Echinochloa colona* Link. and *Cynodon dactylon* Pers. which are normally found by the edge of pools on heavy soil and do not appear to grow on sand. They are the most popular grasses for making into hay and give excellent results. Also found in similar habitats is *Sporobolus helveolus* Durand and Schinz. (Ar. 'lukh') which is of interest as several samples analysed have contained more phosphoric acid than lime, which makes the grass unsuitable for horses fed on dura.

Grazing is good in the Baggara areas during the rains, and after 2 months thin cattle become covered with flesh. Cows also produce appreciable milk, up to 20 lb. *per diem*. When the grass dries up it loses its seeds and some leaves, and nothing more or less than fibrous straw of low protein content remains. Cattle gradually lose condition, aggravated later in the year by the increased distances they have to walk for water.

Unseasonable rains cause untimely germination of seeds. Arabs report, however, that an area can be germinated many times without any obvious loss of grass, which may be due to the different depths at which the seeds are buried or to variation in the amount of moisture necessary to germinate seeds of the same species. It is certain that the common grasses have a very strong survival value.

It is not known if grasses which grow in any area vary from year to year, or if any particular grass is on the increase at the expense of others, although it has been reported that 'haskanīt' (*Cenchrus biflorus* Roxb.) is spreading into the Kababish country.

The only deficiency disease reported is osteodystrophia fibrosa in horses, produced by an unbalanced P/Ca intake. It is due to feeding on dura grain plus poor quality hay (straw). The disease does not occur in Khartoum and in the Gezira where alfalfa, with plenty of calcium, is fed.

Swamp Grazing in Upper Nile Province

In the semi-permanent swamps of the south live two well-known cattle tribes, the Dinka and the Nuer. Although the former is the larger and

more sophisticated, there is an excellent account of the latter by Evans Pritchard in *Sudan Notes and Records*, xxi, 1938. They live in an almost dead-flat clay plain, predominantly covered in grass, threaded with very slight depressions which link up with the main rivers, and broken by occasional sandy ridges and knolls and belts of trees. The main rains are from May to October, and coincide with flood-waters brought in from outside. From the middle of June the whole surface of the country is under water except for the occasional higher land on which are perched the villages. As the rains cease the rivers also fall; and under the blazing sun the soil and grasses quickly dry. By mid-November the grasses can be burnt, and by mid-December water for men and herds is as scarce as it is excessive in the wet season.

The spring, when early rains fall and grasses begin to grow, is a season of fatness; grazing is widespread and selective. Conditions gradually become more difficult; some of the best grasses grow tall and rank, and inundation often leads to appreciable reliance on the short grasses and weeds of the village ridges. At the beginning of the dry season the tall grasses dry up and seed. So soon as can be fully effective the grasses are burnt, not only to facilitate movement but to produce grazing from such of the grasses as will throw up tender shoots. Some of the best grasses await the next rains; while there are years when growth of the others is poor. Surface water quickly becomes a problem and there is migration to the more permanent supplies which themselves are often none too plentiful.

Camel Grazing in the 'Gizu'

Newbold in *Sudan Notes and Records*, vii, 1924, gives an account of the important winter grazing of camels on the great steppe area where the borders of Dongola, Kordofan, and Darfur meet, lying between latitudes 15° 30′ and 17° and longitudes 25° and 29°, and embracing some 24,000 square miles of variable grazing. In this rolling 'qōz' country of stabilized sand-dunes there is a characteristic semi-desert vegetation of an annual growth of small herbs and grasses together with very thin permanent bush. Part of this vegetation, due to its nature and to the cold desert winter, remains green from the end of the rains in September until the following April; and the important Kababish tribe sends its herds of camels to fatten from October till the end of March or later, after which they return southwards. During this absence of 6 months the animals drink nothing, but are supported by the moisture of the fodder. This area is called the 'gizu', an Arabic term connected with absence of drinking; and the organized annual departure of the herds to the grazing, after a last drink of water with plenty of rock-salt, is a momentous occasion in the life of the tribe. For the herdsmen the shortage of water and the cold make the life a hard one.

Water-supplies

For cattle and sheep regular and frequent water is essential; and unfortunately in the central and northern Sudan the supply is, on the whole, much more limiting than fodder. The only permanent rivers serving the

pastoral areas are the Blue and White Niles; the few others like the Atbara, Rahad, and Dinder are seasonal, although pools are left in the dry season. In these cases the available fodder within the grazing radius becomes limiting. In other areas, water-supply is a very potent factor during the long hot and dry season when many seasonal watercourses and natural pools are dry, and thirst intense. For animals which cannot move to the rivers recourse is made to the limited supplies of water-holes, wells, and such water as remains in natural and artificial pools. The available fodder is then regulated by the distance from water; and either water or fodder may become limiting. In the latter case cattle may congregate around a watering place, gradually wasting away from lack of food, as can occur for example in the Gash Delta in May and June.

It is also to be noted that water-supplies, when limited, are often also filthy for both man and beast.

Some Conditions in the Irrigated Areas

The largest single area in which crops are raised by regular watering, and in which water is available all the year round in canals or in nearby perennial river, is the Gezira. Of very considerable combined importance are the various schemes between Kosti and Jebel Aulia on the White Nile, and between Khartoum and Halfa on the Main Nile. The area of purely riverain land along the Blue Nile is relatively small.

The population is considerable, and numerous livestock are kept: cattle, donkeys, sheep and goats, and some camels. Donkeys and camels provide transport. Bulls are used for ploughing; cows, sheep, and goats give a milk supply; and all provide some meat.

Although there is an assured supply of water, food is often desperately short. With exceptions, the only crop grown especially for animals is 'lubia' (*Dolichos lablab* Linn.); for the rest they rely on the straw and stubble of grain crops, together with suitable weeds appearing in the rains or between crops, and the haulms of peas and beans in the north. In some places there are periodic movements to the pastoral areas and to land from which storage water of the dams is receding.

The Gezira

It is very difficult to give a succinct account of animal nutrition in this large irrigated area where goats, sheep, cattle, donkeys, and camels are kept.

Rains, which vary from 18 in. in the south to 8 in. in the north, last from May until October, but are only appreciable in July and August when weed growth also commences. The remainder of the year is dry, and in some months very hot.

As a background the following calendar refers to working bulls and cows-in-milk of tenants in the *Southern Gezira*:

Aug.–Nov. Grazing on weeds of resting land, canal banks, &c. The animals are usually in fairly good condition. Working bulls may also be given a ration of 4–6 lb. of dura grain *per diem*.

Dec.–Jan. Grazing on dura stable. Working bulls are given dura straw.

Feb.–April. Ditto, with addition of drying-out 'lubia' crop. A few tenants cut their 'lubia' and feed it.

May. The cotton crop is now finished; and, prior to pulling out, stock are allowed to enter the fields.

June–July. A starvation period ensues. If available, a little dura straw is fed at night, but the great majority of animals are turned loose to pick up whatever they can on the remains of the three crops, and of weeds on canal banks. Working bulls fare better; the Company issues 5–8 lb. of cotton seed per bull *per diem*; and provision is made for bull owners to store dura straw at central points.

In the same area there are a large number of cattle which fare worse; during the famine period June–July many villages by long accustomed practice send their unwanted animals, e.g. cows not in milk, to the river bank and farther south to where grazing is reported to be earlier or better; for the rest of the year the animals are merely sent out to graze on the land surrounding the villages. Put shortly, most animals are expected to pick up a living wherever they can. Cattle in poor condition may be given a little dura grain; and a few of the better owners feed a small daily ration during the season when grazing is most scanty. Use of sesame cake is practically unknown; and the locally produced cotton seed is mainly exported.

As regards the *Northern Gezira* rainfall is appreciably lighter than in the south, and weeds less. Dura straw and 'lubia' are important. Of the former wise owners usually put aside in December a quantity for use in the period June to October. Full use of the 'lubia' is not made, as a crop of beans is preferred to several cuts for fodder. There is occasional use of simsim cake, and cotton seed when procurable is in great demand. For several of the summer months working bulls are given a ration of dura straw. On the whole the cattle receive as good attention as is possible in the circumstances.

In this northern area transport camels are well looked after. Owners endeavour to procure a crop of 'lubia' for them to augment general grazing on weeds mostly near the river. Goats and sheep are said to have increased to such an extent that they are a menace. Allowed to find their own food they trespass and make life more difficult for camels and cattle; and by continual scraping at odd pieces of weed they loosen the top soil and tend to increase risk of wind erosion.

On the western edge of the *Central Gezira*, under the aegis of the Kassala Cotton Company, life is much the same except for the ploughing bulls which are kept by the tenants under the supervision of the company. In addition to what they can pick up, 2 acres of 'lubia' per bull are grown in September to October. One cut is taken in late November and a second cut in late December; both are stacked as hay. The crop is then allowed to mature and grazed *in situ*. The conserved fodder serves the animals during the lean summer period, at which time 6 lb. of cotton seed is fed *per diem*. Throughout the year a dura grain ration of 6 lb. *per diem* is fed to them.

Female milking-goats are generally fed a small dura ration during the

summer. Sheep pick up what they can at all times. Camels also range, but during the working season their main diet is dura straw.

As will be realized, life for most animals is a hard one. Conditions will have to be improved; but in the process the realities of the situation will also have to be faced. There is much cotton seed produced; local use, perhaps of cake, would require utilization of the resulting manure. The same applies to increased growing of fodders which mean water and alteration of economic factors. Mechanization can cut down the number of bulls and allow more food for milking-animals. Meat is perhaps best bought from outside. In the process of arriving at a suitable mixed farming, a social outlook of the people is essential.

Natural Foodstuffs

Trees and Shrubs

The browsing animals, camels and goats, in many parts have to exist almost entirely on shrubs and trees for the greater part of the year.

Cattle and sheep, although they do not browse in the true sense, pick up the seed pods and leaves of a wide variety of trees and shrubs. In the Baggara areas of Kordofan and Darfur Provinces it is common to see calves feeding in this way in the vicinity of well-fields. They are often past weaning age and appear to pick up little else at pasture. Mature cattle also pick up edible seeds and pods which come their way in the normal course of grazing through scrub. Throughout the Atbara and Setit river areas south of Qōz Rageb in the eastern Sudan the Butana sheep flocks exist for considerable periods on Acacia pods.

A list of those more commonly browsed by camels is given in Appendix I (p. 684). The fallen seed-pods and leaves of some are consumed by cattle and sheep. Goats will, of course, eat almost anything provided that they can reach it.

No local analyses are available, but it is certain from evidence elsewhere that some of these foodstuffs are excellent.

Herbs and Under-shrubs

Attention has already been drawn to the importance of these, and further examples are worthy of record. A provisional list is given in Appendix II.

Two common weeds in the eastern and western Sudan are 'hantud' (*Ipomoea cardiosepala* Hochst.) and 'baghīl' (*Blepharis linariifolia* Pers. and *B. persica* (Burmf.) Kuntze). In the Kassala and Gash areas, during the rains stock grazing on 'hantud' consume little else for about 2 months and 'baghīl' is a useful subsidiary. In parts of the Butana (E. Sudan) 'baghīl' assumes primary importance as camel and cattle feed during periods of the year.

In the rainless north there is a very useful leguminous weed 'kiteih' (*Trigonella laciniata* Linn.) which occurs in some basins after the Nile flood. It closely resembles lucerne in habit of growth but, unlike the latter, only gives one cut per season.

A creeping waterweed (name unrecorded) in the upper Nile is said to be excellent for fattening.

The only analytical data available refer to the crude protein content of seven commonly grazed weeds in the Gezira, growing during the rains on uncropped land. Samples were gathered at a stage of growth comparable to that grazed by animals, fairly mature but still green and growing; values on a dry basis ranged from 15·4 per cent. to 23·9 per cent., with an average of 19·4 per cent., which is very good.

Grasses

A provisional list of those known to be grazed is given in Appendix III on p. 685. As regards analytical data there is a little information bearing on (*a*) mineral status, (*b*) the organic constituents protein, fat, carbohydrate, and fibre.

In 1930, in participation with the Empire survey of natural fodder grasses in relation to the correlation of diseases in animals with mineral deficiencies in the grasses, analyses were made on samples of various grasses—individual and mixed—received through the Veterinary Department from Kassala, Kordofan, Darfur, and old White Nile provinces. Many were collected at the end of the rains (Oct./Nov.), and most of the others still later. The results must therefore be considered as referring to fully matured materials.

In 1936 a further series of twelve grasses from Kordofan Province, collected in each of three stages of growth (young, half-grown, and in flower or seed) in connexion with some drying experiments, was examined more particularly in relation to organic constituents.

Turning to the *inorganic* constituents, available data are summarized in Table I, expressed as percentages of dry matter.

TABLE I

		1930 Series	*1936 Series*
Lime	CaO	0·67	0·58
Potash	K_2O	2·34	..
Soda	Na_2O	0·27	..
Phosphoric acid	P_2O_5	0·36	0·51
Chlorine	Cl	0·44	..
Sulphur	S	0·33	..
Iron	as Fe_2O_3	0·21	..
Silica-free ash		5·6	..
No. of samples examined		12–40	36

Phosphoric acid in the earlier series (of matured grasses) is low, but not at a level which can be associated with phosphatic starvation in animals. Amongst individual analyses is an interesting exception: four samples of 'hamra' grass (*Aristida* sp.), from the old White Nile Province, and collected at different periods, all showed low phosphoric acid together with low lime and crude protein. Averages were:

Phosphoric acid	0·14 per cent.
Lime	0·46 ,,
Crude protein	2·3 ,,

The place of origin is not known. Although symptoms of aphosphorosis (bone eating and osteoporosis) have occasionally been observed, they cannot be tied to any particular cause; and, as mentioned previously, most animals graze over large areas and on many different grasses.

The other data in the table call for no particular comment.

Variations due to degree of maturity are most easily discussed in conjunction with *organic constituents*, for both of which the 1936 series provides some evidence. Results, averaged for twelve grasses and expressed as percentages of dry matter, are given in Table 2. Although showing trends in the expected direction, the differences are not great. Crude fibre—an important factor in digestibility—is high throughout.

TABLE 2

	CaO	P_2O_5	*Crude protein*	*Ether extract (fat)*	*N-free extract (carbohydrate)*	*Crude fibre*
July–August (young) .	0·67	0·59	10·2	1·7	44·0	28·8
August–Sept. (half-grown)	0·51	0·49	8·8	1·6	44·5	33·0
October (in flower or seeding)	0·55	0·45	8·5	1·5	44·3	34·1
Average . . .	0·58	0·51	9·1	1·6	44·3	32·0

The adverse effects of cutting later still are shown by results in the 1930 series for three grasses collected at different periods (Table 3).

TABLE 3

Collected	*% lime*	*% phosphoric acid*	*% crude protein*
November	0·53	0·37	6·9
January	0·57	0·30	4·8
March	0·55	0·27	3·7

Averaging data for the 1930 series according to season, irrespective of district and of nature of grass, similar results are obtained (Table 4).

TABLE 4

Collected	*No. of samples*	*% phosphoric acid*	*% crude protein*
August–September . .	6	0·52	9·0
October	14	0·40	6·6
November	8	0·37	6·4
January	7	0·35	5·4
March–May . . .	7	0·23	3·2

Individual grasses in the 1936 series vary considerably in their composition. Since factors such as environment and season are generally

recognized to have a great influence on composition, it is impossible to associate the variations with botanical nature without much further evidence.

Two other recorded analyses both refer to 'difra' (*Echinochloa colona* Link.) collected in early flower; at Khartoum North a sample showed 17·3 per cent. crude protein on a dry matter basis while a sample from the Gezira was also good, with 14·7 per cent.

It is unfortunate that there are no analyses of organic constituents except in the growing-season. Even so, it is clear that many grasses must become very fibrous and low in protein, to an extent that they form only sub-maintenance rations. Drying of immature grasses is, however, the exception.

A small amount of grass is cut when green and stacked after short drying, e.g. by the Sudan Defence Force for its animals. Again, along the river bank north of Khartoum, after the flood has subsided, some river grass is cut and dried for sale in Omdurman; some is not cut until dry. Good 'difra' (*Echinochloa*) hay has been obtained at the nearby School of Agriculture by the first method.

Some hay was made from a *Sporobolus* species growing near Wad Medani. Although the grass was cut at the early flowering stage and well 'made', palatability and composition were not of a high order, viz.:

Crude protein . . .	7·5	per cent.
Ether extract . . .	0·5	,,
N. free extractives . .	35·6	,,
Crude fibre . . .	48·8	,,
Ash	7·6	,,

Fibre was very high, and no doubt the limiting factor.

Progress amongst the cattle-owning tribes on the lines of drying better grasses is very dependent on greatly improved water-supplies to lessen nomadic movement, and must be preceded by careful practical inquiries.

Feeding Value of Grasses

It is known that where fodder is ample the cattle practise selective feeding. All the same it may be of interest to readers if a rough calculation is made of the feeding value of the 1936 series of grasses.

There are as yet no experimental measurements on digestibility coefficients. Approximate values of protein 55 per cent., fat 50 per cent., carbohydrate 55 per cent., and fibre 55 per cent. will be used; and, in calculating the starch equivalent, 0·58 will be subtracted for each 1 per cent. of total crude fibre.

The *maintenance ration* for a 1,000-lb. bull or cow is taken as 6 lb. starch equivalent and 0·6 lb. digestible crude protein; the *production ration* for 1 gallon of Sudan milk (high in fats and solids), or for about 1·2 lb. increase in live weight *per diem* as 3·0 lb. starch equivalent together with 0·7 lb. digestible protein.

Considering the thirty-six individual samples of grasses. The starch equivalent requisite for maintenance and for the above milk yield (or live-weight increase) is contained in 26 to 36 lb. of dry matter, with an average of

30lb. (20lb. maintenance plus 10lb. production). The corresponding protein requirement is met by 15 to 62 lb., again with an average of 30 lb. Although the averages are identical the feeding-value is limited by protein in only one-quarter of the cases; in short, it is the starch equivalent which is mainly limiting, and this is due to the appreciable crude fibre at all stages of sampling.

The accepted capacity for 1,000 lb. animals elsewhere is about 25 to 28 lb. of dry matter. The better grasses in the 1936 series are therefore equivalent to about 1 gallon of milk or a live-weight increase of rather over 1 lb. *per diem*. These are low. They are the figures which might be expected by cutting and feeding such grasses whole. On the other hand, during the early rains some better grazing is likely; and also, according to supply, cattle may eat only the more tender parts. During the dry season the position would be expected to be worse; protein tends to fall and crude fibre is likely to increase and in addition more energy is required to cover the demands of nomadic movement. How do these expectations fit in with facts?

Owing to conditions our cattle, for their breed, are quite small and are very slow in coming to maturity; in addition, milk yields are low and loss of condition in the dry season occurs. These defects are known to be greatly improved by good feeding.

Although the total lactation yield of Sudan nomadic cattle is low, the average lactation period under free range conditions is a little more than 5 months. Calves are thrown in the early rains, and more than 80 per cent. of the yield is given on grasses during the rains. Although average yields of a herd are normally very low (perhaps ½ gallon *per diem* per cow of average weight, probably near 700 lb.), a certain number of animals give 1½ gallons and upwards in addition to putting something on their backs as a reserve for the often sub-maintenance ration of the dry season. That is, poor breeding as well as fodder has to be borne in mind.

Again, although growth-rate over several years is slow, live-weight increase must often be quite considerable for the few months in the rains when good pasture is available.

Factual data on performance and on the actual grasses and weeds consumed at various times of the year are badly needed. A purpose is served if the above discussion leads to a greater interest in the problem of animal nutrition.

Cultivated Foodstuffs

Grain Crops

Dura Forage. The mature straw ('qassab') of this main food crop is a most useful fodder in the irrigated areas, and progress has been made in its storage. A round stack, similar to an English corn rick, is constructed into which the 'kullega' or bundles are laid as soon as possible after cutting, and while the straw is still only half dry. The heating which takes place in the stack is to its advantage and improves the contents, which show no signs of deterioration when fed to stock 18 months later. It is essential that stacks should be built only on bases which have previously been made termite-proof, whilst care should be taken during and after

construction to ensure that the finished stack is water tight as rain will cause irreparable damage.

An analysis for a sample of Abu Sabain variety at Shambat in 1919 is given in Table 5. It appears hardly better than a maintenance ration, with protein limiting. The position is even less satisfactory if the straw at the Gezira Research Farm is considered; numerous analyses have shown an average content of only 2·5 per cent. crude protein which is therefore highly deficient. As with grain there may well be significant differences associated with conditions of growth (see later).

TABLE 5

	Dura straw	*Dukhn straw*	*Maize straw*	*26 dura grains*	*'Lubia' hay*
Crude fat (per cent.)	2·1	1·4	2·2	3·4	4·2
Crude protein ,,	8·0	1·6	8·4	15·0	19·0
Crude fibre ,,	39·9	45·3	35·8	2·4	22·7
N. free extract ,,	43·2	45·2	44·9	77·2	38·0
Proteids ,,	6·1	1·6	6·9	..	15·4
Amides ,,	1·9	..	1·5	..	3·6
*Starch equivalent	28·0	25·0	33·0	85·0	39·0
*Digestible crude protein	2·5	Low	3·6	10·3	11·2

* Using the average of a few digestibility coefficients found in the literature. The resultant figures, in the absence of factual data, can only be considered approximations for preliminary guidance. Expressed on dry matter.

Near towns like Khartoum there is a certain amount of dura grown for forage. Although there is no information on the value of a crop cut at the flowering stage, it is bound to be better than matured material; even so, the crop is sometimes cut far too late.

The poisoning of livestock here as elsewhere by prussic acid present in dura forage is not uncommon. The acid is formed by hydrolysis of a cyanogenetic glucoside. Native opinion is that the trouble only occurs with plants which have failed to ripen owing to insufficient water and while they are withering; and that only Feterita types are dangerous. The wild or hybrid Sorghums (''adār') also cause similar poisoning.

In 1933 a number of cattle at the Gezira Research Farm died from eating dura 'gassab' grown in 1932. The cause was finally attributed to the effects of locust damage; owing to loss of grain in the milk stage the plants had tillered prolifically, and there was an unusually high proportion of leaf to stalk. This explanation agrees with the following tentative laboratory results:

(*a*) Cyanide is present mainly in the leaves. Both mature and immature leaves contain the poison; but young green shoots dying from lack of water actually contain less than more mature leaves.

(*b*) It appears that the contrast in toxicity of unripe and ripe dura depends mainly on the proportion of leaf to stalk, which is low in the mature crop. Moreover, the mature leaves are brittle and a part may be lost before the fodder is consumed.

(*c*) The seasonal effect seems to depend on the production of more leaves and less stalk, when the crop is unable to ripen uniformly.

(*d*) There are well-marked varietal differences in cyanide content of the leaves, and the proportion of leaf to the innocuous stalk and head.

(*e*) After ensilage no cyanide is found.

Dura grain is mainly consumed by the human population or exported; a certain and unknown amount is fed to animals.

In 1906–8, twenty-six rain-grown samples showed a high protein content (Table 5), and the grain was obviously an excellent food. Accordingly, about 1912 a large sample was sent to England. At Durham University it was fed as meal to milch cows, and appeared equal to maize meal. At the South-Eastern Agricultural College, Wye, it was again fed as meal to cows; some relished it, some preferred it mixed. The butter was deeper in colour, with a lower melting-point. Sheep readily ate the kibbled (cracked) grain.

In 1940 much lower figures were obtained for protein in samples grown under irrigation after cotton (Table 6). At first it was thought that the preceding cotton crop might be responsible, but samples provided from the Gezira Scheme by the Sudan Plantations Syndicate indicated that the general difference is between rain-grown and irrigated crops (Table 6). The explanation is that, in the Gezira area, under irrigation nitrogen is limiting.

TABLE 6

Origin	*No. of samples*	*% crude protein (on dry basis)*
Gezira Research Farm. N-manuring expt. .	54	8·8
,, ,, ,, Varietal trial . .	180	9·7
Syndicate Area. Rain-grown	24	14·5
,, ,, Irrigated, after rest . .	102	10·5
,, ,, ,, ,, dura . .	97	10·3
,, ,, ,, ,, cotton . .	38	9·6
,, ,, ,, ,, 'lubia' . .	6	9·5
Upper Nile, rain-grown	9	13·6
Nuba Mountains	6	12·9

A few rain-grown samples collected from the Upper Nile grass plains under a grass rotation, and from the Nuba Mountains following cotton, showed good protein contents (Table 6). Some duras grown on rain at the Gezira Research Farm in 1942 and 1943 showed 12 per cent. protein, which is well above the irrigated values.

The above differences are very considerable, and must be considered in valuation for feeding purposes locally or in any attempt to obtain an outside market. Also, the grain should be crushed or bruised to facilitate digestion; this is not always done.

Dukhn (*Pennisetum typhoides* (Burm.) Stapf and Hubbard) is grown on an appreciable scale on rainfall in Kordofan and Darfur Provinces, and under flood irrigation at Tokar. The grain is fed to horses in Darfur

Province. It is relatively rich in crude protein; four samples from Kordofan Province showed an average of 15.9 per cent. on a dry basis.

The only analysis of the straw is for an irrigated sample from Shambat in 1920; it was very poor in crude protein (Table 5).

Wheat Straw. In peace-time the cultivation of wheat is virtually confined to the Northern Province under irrigation. After threshing the heaps of straw are normally eaten *in situ*, although some is moved for use elsewhere. A recent analysis for a crop at the Gezira Research Farm showed 1·8 per cent. crude protein, which is even lower than that in dura straw at the same place. It is generally reckoned as an inferior fodder.

Maize. Cultivation of this crop is increasing. The results for a sample of mature straw from Shambat in 1929 are given in Table 5. The figures are very similar to those for dura from the same place.

Leguminous Crops

Lubia (*Dolichos lablab* Linn.). Appreciable areas of this annual crop are grown in the basic rotations of the Gezira and of the White Nile Alternative Livelihood Schemes, and in Northern Province, all under irrigation.

Some is used as a plain forage crop, some is allowed to mature for collection of seed. Utilization by cattle is normally by grazing *in situ*, but stacking is actively encouraged to help to tide over the difficult early summer period. A product of excellent quality and greatly relished by all livestock has been obtained by cutting and stacking the mature crop in a green state. No time should be wasted between the two operations, otherwise considerable loss of leaf will occur; each layer should be thin and allowed to dry sufficiently before covering. Some fermentation occurs, but this improves the palatability of the hay which, when fed to cattle, brings them to a high degree of condition. At Abd el Māgid, prior to feeding and to prevent loss of leaf, water is sprinkled on the stacks.

An analysis of a crop grown for forage at Shambat is given in Table 5. As expected, the material shows up as an excellent fodder, agreeing with its local reputation as a first-class milk producer.

Analyses of crops at the Gezira Research Farm have shown lower protein content (11·9 per cent. and 14·1 per cent. respectively on a dry basis). Such variations are to be expected, dependent on degree of maturity and proportion of leaf to stalk.

Bersīm el Hegāz (*Lucerne* or *Medicago sativa* Linn.). This perennial crop is grown on a limited scale under irrigation, and yields large quantities of first-class fodder. Cost of production is high, and use is therefore confined to special animals. It is usually fed as hay (Ar. 'drīs') in which form it can be baled, transported, and stored; if fed fresh to cattle it is very liable to cause hoven.

The main analyses available refer to six fresh samples collected just before flowering at the Gezira Research Farm. Averaged, and in percentages on an oven-dry basis:

Crude protein	28·5	Lime, CaO	2·0
Phosphoric acid, P_2O_5	0·71	Magnesia, MgO	0·45
Chlorine, Cl	0·60	Potash, K_2O	3·48
Sulphur, S	0·52	Soda, Na_2O	0·30

These results compare well with published data. Values, however, vary with factors such as degree of maturity and ratio of leaf to stalk. Thus a sample of commercial 'drīs' at Khartoum had on a dry matter basis:

Crude protein . .	12·6 per cent.
Phosphoric acid .	0·46 ,,
Lime . . .	2·01 ,,

Both protein and phosphate are much lower.

Stalks are less nutritious, as shown by some samples at the Gezira Research Farm:

Leaves . . .	27·3 per cent. crude protein
Stalks . . .	10·0 ,, ,, ,,

Other Legumes. In Northern Province the dry haulms of field peas and of haricot beans are grazed. No analyses are available. The hay of groundnuts is considered very good food, although very brittle and dusty.

Miscellaneous Foods

Sesame Cake ('ombāz'). A certain amount of this material is fed to animals. Locally this cake contains about 13 per cent. oil and 41 per cent. crude protein, and is the only available concentrate until more cotton seed is crushed. It has a reputation for milk and fattening, but its cost is high. The cake has a tendency to go hard and that crushed in native presses often contains much sand.

Cotton Seed and Cake. In the Nuba Mountains area it is not profitable to export the cotton seed (American type) from the ginning factories. Some is used as fuel and some is crushed; the remainder is available to the local cattle, who eat and thrive on it. This is surprising as uncooked cotton seed is generally supposed to be poisonous, and the fuzzy American seed might be expected to cause balling in the intestines. It may be that the cattle eat sufficient dry mature grass at this particular time of the year to dilute the seed.

The cake so far available to animals is negligible. If and when the position changes, the value of the cake will vary according to the initial protein content of the seed which is known to be quite variable.

Cotton Plants. In the cotton areas fodder is extremely scarce at the time when the cotton crop is finishing; and the old leaves and green secondary growth form a limited but undoubtedly good source of food to the hungry animals. The supply is consumed within a few weeks.

Sweet Sorghum. Trials of a few varieties have been made at the Gezira Research Farm and at Abd el Māgid. They grow well and are liked by the animals.

Salt Bushes. In some parts of the world they form excellent fodders. Three species (*Atriplex muelleri* Benth., *A. halimoides* Tineo., and *A. semibaccata* R. Br.) have been tried at the Gezira Research Farm; quite apart from certain cultural difficulties they are disliked by the animals.

Mesquite (*Prosopis juliflora* D.C.) is grown to some extent as a protection against encroachment of sand. It is hardy and drought resistant, gives valuable shade and shelter, and yields large quantities of seed pods which are readily eaten by stock.

An analysis of local pods is given below:

	Per cent.		Per cent.
Moisture	5·6	Carbohydrate	51·0
Ash	5·1	Protein	10·9
Crude fibre	25·4	Phosphoric acid, P_2O_5	0·58
Fat	2·1	Lime, CaO	0·73

Prickly Pear (*Opuntia* sp.). This introduction spreads at a great rate in suitable situations and produces a large bulk of fodder; but its importation to, and establishment in this country has not been encouraged in case it might get out of control as in some other countries.

Grasses. The area of cultivated grasses is negligible. Sudan grass, Arabic 'garāwi' (*Sorghum sudanense* Stapf.), is grown under irrigation in the north; it is a heavy yielding crop which produces fodder at all seasons, can be cut several times, and is normally consumed green. In the south various grasses, indigenous like guinea grass (*Panicum maximum* Jacq.) and Rhodes grass (*Chloris gayana* Kunth.), are under trial for special herds.

In Northern Province, 'nagīl' (*Cynodon dactylon* Pers.) is a common weed on irrigated land; and it is left amongst certain crops, such as cotton, which are not ruined by the practice. In fact it is stated that when cotton was extensively grown, the crop of this weed was often considered more valuable than the cotton itself—so great is the demand for food for animals.

Silage. Any fodder crops preserved in a semi-green condition by a controlled fermentation can be termed ensilage, and almost all Sudan crops except cotton can be preserved by this method. The most suitable are 'lubia', millet, and maize; and a combination of 'lubia' with one or the other should give better results than one crop by itself. Millet, cut green, and 'lubia' in the proportions 1 : 2 make a good mixture. Consolidation is greatly facilitated if all materials are chaffed prior to being ensiled. The quality is improved by the addition during filling of molasses at the rate of 3 to 4 gallons per ton of green material, but this is not absolutely essential.

There are two types of silos which may be termed suitable for the northern Sudan, the pit and the mud wall, and both are within the scope of the ordinary cultivator as regards labour and cost. For the *Pit Silo* it is most essential that the site should be in ground which is high and dry and where drainage is adequate or possible. A soil which cracks badly should be avoided, although mud plaster on the sides of the pit will go a long way towards making it airtight. The *Mud-wall Silo* is not recommended unless conditions of soil and climate preclude the employment of the cheaper pit variety. The walls of mud brick should be wider at the base and mud plastered inside and out. The *Sisalkraft*, an improved type of silo consisting of a wire netting framework with a sisal fabric lining, has been introduced to the Sudan, but has yet to justify the good reputation it enjoys elsewhere.

Although the trials made at the Gezira Research Farm and Abd el Māgid in the Gezira, at Maridi and Yambio in the southern Sudan, and in Northern Province, have only been few and results variable, storage of materials as hay is likely to be more popular, at least in the northern Sudan. It entails less work and there seems to be more chance of success.

Conclusion

In the *pastoral areas* as a whole there is more than ample natural fodder produced in the rains. Its availability is gravely curtailed by limited surface-water supplies during the dry season, often leading to local overgrazing and famine. Not only is more water required, but also a better distribution in the form of wells, artificial pools, and damming of suitable depressions. Ideally, such a programme has to be co-ordinated with control of the number and kind of livestock required for the nutritional and other needs of the people, and by the possibilities of export of animals and their products. At the same time breeding is involved, since a poor animal can require as much food and water as a better one.

Improvement of the pastures themselves cannot be contemplated except in so far as the bad effects of overgrazing, including those due to selective feeding, can be overcome by an expansion of water-supplies and control of grazing. And it is only then that, on an appreciable scale, progress can be expected in the utilization of stored hay—a practice which is incompatible with extensive nomadic movement.

Although the major needs are for more adequate diet and water-supply, progress will be more rapid if it proceeds *pari passu* with a knowledge of what the animals require and of the value of the available fodders.

The problem of *irrigated areas* with perennial water near at hand is very different and also very difficult. Fodder is notably scarce at times; but to produce special crops is expensive and not always possible without serious reaction on the production of more directly economic crops.

Since meat and 'samn' (clarified butter or ghee) are cheaper to produce in the pastoral areas, food is required principally for working animals and for milk production although fattening must of course be considered. At the present time, although more fresh milk is needed for improved nutrition, the claims of working animals are often hard to fulfil.

Mechanization is a means of reducing the need for the latter. For milk production there are several good foodstuffs possible (dura grain, 'lubia', alfalfa, cotton seed, and sesame cake) provided that the economic factors can be surmounted. Success is probably largely dependent on proper utilization of animal manure to produce the maximum increase of economic crops per feddan. Where legumes are grown the optimum conditions for enriching the soil must be worked out fully.

Animal and human nutrition are so closely allied that progress in the former is vital to the promotion of the health and true welfare of the people. Facts of many kinds are urgently needed on which to base a sound policy.

APPENDIX I

TREES AND SHRUBS[1]

1. *Acacia albida* Del. ('harāz'). Young shoots and fruits eaten with relish by camels.
2. *Acacia flava* (Forsk.) Schweinf. (= *A. ehrenbergia* Hayne) ('salam'). One of the best for camels.
3. *Acacia mellifera* Benth. ('kitr'). In dry season useful for pods only; but in rains young shoots have a valuable tonic effect on camels.
4. *Acacia orfota* (Forsk.) Schweinf. (= *A. nubica* Benth.) ('la'ot'). Inferior browse feed for camels and goats; sheep and cattle eat pods.
5. *Acacia raddiana* Savi (= *A. tortilis* Hayne) ('samr'). A second-best camel fodder.
6. *Acacia senegal* (L.) Willd. (= *A. Verek* Guill. & Perr.) ('hashāb').
7. *Acacia seyal* Del. ('talh'). Eaten sparsely by camels.
8. *Acacia sieberiana* DC. (= *A. verugera* Schwfth.) ('kuk'). Eaten by camels when no other grazing available.
9. *Acacia tortilis* (Forsk.) Christensen (= *A. spirocarpa* Hochst.) ('seyal'). One of the best for camels.
10. *Adansonia digitata* Linn. ('tebeldi'). Leaves readily eaten by camels in early rains.
11. *Balanites aegyptiaca* Del. ('heglīg'). Leaves and shoots eaten by camels; fruits a mild purgative.
12. *Bauhinia rufescens* Lam. ('kulkul'). Excellent food for camels.
13. *Boscia senegalensis* (Pers.) Lam. ex Poir (= *B. octandra* Hochst.) ('mokhēt'). Eaten by camels.
14. *Cadaba glandulosa* Forsk. ('kurmut sighaiyir'). Good camel fodder. Slightly purgative.
15. *Capparis decidua* Pax. ('tundub'). Chief camel food in some places, but of low feeding value and only eaten in absence of other food.
16. *Capparis tomentosa* Lam. ('hekabīt'). Variously stated to be excellent food, and also poisonous, for camels.
17. *Combretum aculeatum* Vent. ('soghēt'). During rains the leaves are an excellent camel food, greedily eaten.
18. *Commiphora africana* Engl. ('qafal'). Eaten by camels and cattle.
19. *Cordia abyssinica* R. Br. ('inderāb intaya'). Excellent camel food.
20. *Cordia gharaf* Ehrenb. ex. Aschen (= *C. rothii* Roem. & Schultes) ('inderāb qimbil'). Camels.
21. *Dichrostachys glomerata* Choiv. (= *D. nutans* Benth.) ('kadāda'). Leaves are readily eaten by camels; sheep and cattle eat pods.
22. *Grewia flavescens* Burret. Small bush readily eaten by camels.
23. *Gymnosporia senegalensis* Lam. ('yoi'). Excellent for camels.
24. *Hyphaene thebaica* Mart. ('dōm'). Eaten by horses, camels, and goats, sparingly by camels.
25. *Leptadenia heterophylla* Decne. ('luwēs'). Excellent camel fodder.
26. *Leptadenia spartium* Wight. ('merakh'). Camels.
27. *Loranthus acacia* Zucc. Tree-parasite; very good camel fodder.
28. *Maerua crassifolia* Forsk. Twigs are greedily stripped of their small leaves by camels.
29. *Premna resinosa* Schauer. ('sa'at'). Greedily eaten by camels.
30. *Salix aegyptiaca* ('ban'). Favourite with young camels.
31. *Salvadora persica* Garein ('arāk'). Fair camel food. Camels bred and reared on it are generally inferior in type.
32. *Sclerocarya birrea* Hochst. ('homēd'). Leaves and small branches eaten readily by camels. The fruit is eaten by most animals.

[1] The comments in these appendixes are based on available information, and in some cases undoubtedly have more general application.

33. *Stereospermum kunthianum* Cham. ('khashkhash'). Branches and leaves greedily eaten by camels.
34. *Tamarindus indica* Linn. ('aradēb'). Browse feed for camels and goats; sheep and cattle eat pods.
35. *Ziziphus spina-Christi* Lam. ('sidr'). A second-best camel fodder, readily eaten.

APPENDIX II

HERBS

1. *Aristolochia bracteata* Retz. ('umm galagil'). Very good feed for camels.
2. *Blepharis persica* (Burm. f.) Kuntze (= *B. edulis* Pers.) ('silih'). Good camel fodder.
3. *Blepharis linariifolia* Pers. ('bighēl'). Relished by all animals.
4. *Boerhaevia repens* Linn. Goats and sheep in Nuer country.
5. *Corchorus olitorius* Linn. ('melukhiya'). Grazed in Gezira.
6. *Cornulaca monocantha* Del. ('hadd'). Fair camel fodder.
7. *Digera arvensis* Forsk. ('lablab ahmar'). Grazed in Gezira.
8. *Dipterygium glaucum* Dec. ('safeira'). Camels.
9. *Emilia sagittata* DC. Goats and sheep in Nuer country.
10. *Glycine Borianii* Baker. Ditto.
11. *Heliotropium europaeum* Linn. ('danab el aqrab'). Grazed in Gezira.
12. *Indigofera arenaria* A. Rich ('dirmi'). Great favourite with camels.
13. *Indigofera oblongifolia* Forsk. (= *I. paucifolia* Del.) ('dahassir'). Good camel fodder.

    Note: There are many other *Indigofera* spp., some of which are almost certainly eaten.
14. *Ipomoea cardiosepala* Hochst. ('hantūd'). A valuable fodder for all livestock. When first eaten it acts as a purgative.
15. *Ipomoea cordofana* Choisy. ('tabr'). Another valuable fodder.
16. *Ipomoea reptans* Poir. Sheep and goats in Nuer country.
17. *Justicia matammensis* Oliv. ('wangrial'). Ditto.
18. *Merremia pedata* Hallier f. Relatively good pasture for camels.
19. *Momordica balsamina* Linn. Said to be a good camel fodder.
20. *Morettia phileana* DC. ('tagha'). Good camel fodder.
21. *Neurada procumbens* Linn. ('sa'adan'). Very good 'gizu' grazing.
22. *Phyllanthus niruri* Linn. ('sorēb'). Grazed in Gezira.
23. *Picridium tingitanum* Desf. ('molēta'). Relished by all stock.
24. *Portulaca quadrifida* Linn. Goats and sheep in Nuer country.
25. *Rhynchosia* sp. ('serēsri'). Grazed in Gezira.
26. *Scleria foliosa* A. Rich. Goats and sheep in Nuer country.
27. *Suaeda fruticosa* Forsk. ('adlīb'). Readily eaten by camels.
28. *Zornia diphylla* Pers. Useful fodder.
29. *Zygophyllum simplex* Linn. Camels.

APPENDIX III

GRASSES (ANNUAL AND PERENNIAL)

1. *Andropogon gayanus* Kunth. ('gau'). Favourite young grass in Nuer country Shoots quickly after burning.
2. *Anthephora elegans* Schrad.
3. *Aristida adscensionis* Linn. ('hemra'). Common grass of plains, largely collected for stock feed.
4. *Aristida ciliata* Desf. ('nissa'). A 'gizu' grass.
5. *Aristida funiculata* Trin. & Rupr. ('gau', &c.). Common grass of plains, probably eaten.
6. *Aristida mutabilis*. Trin. & Rupr. ('dunbalab'). Moderately good for camels.
7. *Aristida plumosa*. Linn. ('sumeima'). Greedily eaten by camels.

8. *Aristida sieberiana* Trin. ('sumeima').
9. *Aristida steudeliana* Trin. & Rupr. ('danabaya'). Widely distributed and probably eaten.
10. *Brachiaria isachne* Stapf. Good, widely distributed.
11. *Brachiaria mutica* Stapf.
12. *Brachiaria obtusiflora* Stapf. ('umm chirr'). Excellent grass; ripe seeds are edible; does not shoot after burning.
13. *Cenchrus biflorus* Roxb. (= *C. catharticus* Del.). The true 'haskanit'.
14. *Cenchrus ciliaris* Linn. (= *Pennisetum cenchroides* Rich.). The false 'haskanit'.
15. *Chloris villosa* Pers. Good fodder, in desert regions.
16. *Chloris virgata* Swartz. ('timala').
17. *Cynodon dactylon* Pers. ('nagīl'). Excellent and widespread.
18. *Cyperus rotundus* Linn. Sheep and goats in Nuer country.
19. *Cyperus* sp. ('dīs').
20. *Cyperus* sp. ('ashub'). A good 'gizu' grass.
21. *Dactyloctenium aegyptium.* Beauv. ('korēb', 'umm asabi'). Good, widely distributed. Seed eaten at times.
22. *Dactyloctenium glauciphyllum* Courb. Desert grass, readily eaten by cattle, sheep, and goats, but dangerous to horses if eaten in large quantity.
23. *Demostachya* sp. ('zobat').
24. *Digitaria debilis* Wild.
25. *Digitaria horizontalis* Wild.
26. *Echinochloa colona* Link. ('difra'). One of the best, widely distributed.
27. *Echinochloa pyramidalis* Hitchc. & Chase ('umm sūf'). A common plant in swamp regions (Sudd). One of best in early rains, but grows tall and rank. Grain sometimes used as food.
28. *Echinochloa stagnina* P. Beauv.
29. *Eleusine flagellifera* Nees. ('homra'). Moderate for camels.
30. *Eleusine indica* Gaertn. ('el kog').
31. *Enneapogon elegans* Stapf. ('umm asābi'').
32. *Eragrostis aspera* Nees. ('hemēra'). Moderate for camels.
33. *Eragrostis tremula* Hochst. ('binnu'). Moderate for camels.
34. *Eriochloa nubica* Hack. & Stapf. Eaten avidly by goats and sheep in Nuer country, but not relished by cattle.
35. *Hackelochloa granularis* O. Kuntze (= *Manisuris granularis* Sw.).
35*a*. *Heleochloa schoenoides* Hosk. ('gughēb'). Riverain grass, sometimes collected and fed to animals.
36. *Heteropogon contortus* Roem & Schult. When mature the sharp-pointed seeds stick in the mouth and penetrate the skin.
37. *Hyparrhenia* spp. Grazed after burning.
38. *Ischaemum brachyatherum* Fenzl. Excellent for camels. Relished when young by cattle in Nuer country, but too rank when mature.
39. *Melinis minutiflora* P. Beauv.
40. *Oryza barthii* Chev. ('ruzz'). Marsh grass in Nuer country, very useful at end of dry season.
41. *Oryza punctata* Kotschy. ('ruzz el wadi'). Fed green to camels.
42. *Panicum maximum* Jacq. (Guinea Grass). Indigenous in southern Sudan.
43. *Panicum repens* Linn.
44. *Panicum turgidum* Forsk. ('tomam').
45. *Paspalidum desertorum* Stapf. ('mordēb'). Good in young stages.
46. *Paspalum commersonii* Lam. (= *P. scrobiculatum* Linn. var. *commersonii* Stapf.). Reputed unwholesome at time of ripening.
47. *Pennisetum polystachyon* Schult.
48. *Pennisetum purpureum* Schum. (Elephant Grass, or Napier's Fodder). Occurs in southern Sudan.
49. *Pennisetum ramosum* Schweinf. Grazed when young. When mature, the stiff heads cause irritation to the eyes of cattle.
49*a*. *Rhynchelytrum repens* (Willd.) C. E. Hubbard (= *Tricholaena rosea* Nees.).
50. *Rottboellia exaltata* Linn. f. When dry, the hard-pointed glumes make the grass unpalatable.
51. *Schmidtia pappophoroides* Steud. ('el milēha').

52. *Schoenefeldia gracilis* Kunth. Good grass for camels.
52*a*. *Setaria chevalieri* Stapf. (= *S. sulcata* Raddi).
53. *Setaria lynesii* Stapf. & Hubbard. Shoots quickly after burning.
54. *Setaria pallide-fusca* Stapf. & Hubbard. Useful at height of rains in Nuer country, but not relished.
55. *Setaria phacelata* Stapf. & Hubbard ('danab el kalb').
56. *Sorghum arundinaceum* Stapf. (''adār'). ''Adār' is also a general term for wild annual sorghums, which of course can be grazed.
57. *Sorghum dimidiatum* Stapf. Eaten young; becomes too rank.
58. *Sorghum sudanense* Stapf. ('garāwi').
59. *Sporobolus festivus* Hochst. ('umm tak').
60. *Sporobolus helvolus* Durand & Schintz (= *S. glaucifolius* Hochst.) ('lukh').
61. *Sporobolus pyramidalis* P. Beauv. Shoots quickly after burning; useful but not greatly relished.
62. *Sporobolus* sp. ('tamar el far').
63. *Themeda triandra* Forsk.
64. *Tricholaena sphacelata* Benth.
65. *Urochloa lata* Hubbard (= *U. insculpta* Stapf.).
66. *Urochloa reptans* Stapf.

CHAPTER XXIV

FERTILIZERS AND MANURES

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Introduction

IN the account which follows it will be seen that emphasis is almost entirely on nitrogen, and that reference is chiefly made to experiments on the Gezira Research Farm at Wad Medani in the large irrigated part of the Gezira. Since the earliest days of scientific work at Khartoum it has been recognized that the predominant need of our alkaline soils is nitrogen. With the opening of the Sennar Dam the irrigated Gezira became of outstanding importance financially, and for various reasons demanded an extensive experimental programme. In carrying out this programme, world advances in experimental technique have been employed; and this, together with the continuity of many of the experiments, has made the results at the Gezira Research Farm the only sound basis for many conclusions.

The site of the main research farm within the Gezira Scheme, and the overwhelming importance of its main crop to the Sudan, have of necessity limited most of the results quoted to cotton. Nevertheless, they are a guide for considerable areas of the country, and will be checked when work extends to other parts, including the relatively small belt of acid soils in the south, as peace-time conditions are re-established.

The work of many, chemists and others, has been drawn upon, and acknowledgement is made to them all. Thanks are due to Dr. Henry, Government Analyst, for access to his files, and to colleagues, especially Dr. F. Crowther, for helpful advice. Finally, in the following pages, all data quoted refer to those obtained at the Gezira Research Farm unless noted otherwise.

Sulphate of Ammonia

A large number of experiments employing sulphate of ammonia, chiefly for cotton, have been carried out at Medani and in the Gezira. Owing to its uniform composition (21 per cent. N) and easy application, and to the unfailing response of crops, the results form a yardstick for all manurial trials. The results are discussed in Chapter XX. It is of interest, however, to examine the approximate increases in cotton crop per unit weight of nitrogen in a few experiments.

In every case except No. 6 (continuous cotton) the rotation was three-course of various kinds. The better the yield of the control the bigger was the response, in kantars per feddan, per unit of nitrogen; that is, less efficient use is made of added nitrogen in the poorer seasons (see Chapter XX). On the other hand, the *percentage* increase from manuring tended to be greatest with the lowest yields of the controls.

Experiment	No. of seasons	Rotls N applied per feddan	Yield of seed cotton in big kantars[1] per feddan: Control	With N	Increase in seed cotton: Per cent.	Rotls per rotl N
1 S	9	40	2·59	3·07	19	3·8
2 S	5	"	2·84	3·30	16	3·6
3 S X	6	"	4·33	4·89	13	4·4
4 X	4	"	5·25	6·09	16	6·6
5 X	5	"	5·87	6·77	15	7·1
6 S	7	80	1·28	2·13	66	3·4
7 S	5	"	2·84	3·67	29	3·3
8 X	5	"	5·87	7·39	26	6·0
9 S	5	120	2·84	3·98	40	3·0
10 X	5	"	5·87	7·87	34	5·3

S = Sakel variety; X = X1530 or X1730 variety (rather higher yielding than Sakel).

The problem is, however, very complex. Increases have been shown (Chapter XX) to depend on factors such as dates of application and of sowing, on spacing and watering; in addition there is some evidence that response is greater on the poorer land of the northern Gezira, as indicated in the following table; the yields are averaged for the same four seasons of a standard Sakel variety in the Gezira observation plots where 600 rotls per feddan of sulphate of ammonia are added:

	Yields of seed cotton in kantars per feddan: Control	Manured	Response in rotls seed cotton per rotl N
North	3·22	5·46	5·8
Central	6·17	7·33	3·0
South	5·19	6·27	2·8

Nitrate of Lime

In recent years a careful comparison has been made between sulphate of ammonia and nitrate of lime (15·5 per cent. N). Unless it is buried the former is 15 per cent. to 30 per cent. less efficient on the strongly alkaline Gezira soil, presumably owing to loss of ammonia which has been detected both in the laboratory and in the field. The difference decreases with increasing rate of application.

Although more efficient, nitrate of lime is not so easy to apply, and is more expensive per unit of nitrogen.

Nitrate of Soda

The soil of the Gezira is already strongly alkaline due to the presence of sodium salts. It would therefore be unwise to increase the sodium

[1] A rotl is approximately 1 lb. A kantar in this chapter is the big one estimated to produce 100 lb. of lint and taken to be 308 lb. of seed cotton.

content by use of nitrate of soda; and the little work done on this fertilizer was confined to Shambat and to the earlier days of the Gezira Research Farm.

This objection cannot be raised in the case of certain other cultivated soils, but no data are available. In general it is to be expected that long-continued application of fertilizer to a strongly alkaline soil will be beneficial when a material with acid residue, e.g. sulphate of ammonia, is used. When the residue is calcium or potassium carbonate the result is not easily predictable for alkaline soils, but if use of fertilizers is extended to the acid soils of the south, such materials are likely to be best; in their class are included nitrate of lime, nitrochalk, and oilcakes.

The normal single application of a nitrogenous fertilizer is such that any deleterious or beneficial effect of its non-transient residue is slight. Investigation of the long-term effects should, and does, form an integral part of fertilizer experimentation.

Nitrochalk

A mixture of ammonium nitrate and calcium carbonate (15·5 per cent. N), this fertilizer has compared equally with, if not better than, sulphate of ammonia at Medani for cotton and dura. In the hot, and for several months humid, climate of the central Sudan decomposition takes place during prolonged storage, and much ammonia is lost. This instability is a drawback unless turnover is seasonal.

Urea and Ammonium Chloride

These fertilizers, with 46 per cent. and 26 per cent. N respectively, have proved equal to sulphate of ammonia for cotton at Medani in the few trials made.

Calcium Cyanamide

This fertilizer has consistently proved less effective than sulphate of ammonia for cotton at Medani. It does not store well in the central Sudan.

Phosphatic and Potassic Fertilizers

There is no clear evidence that, on the soils of the northern and central Sudan, potassium and phosphorus are limiting to yields of the common crops.

At Medani the average yields of cotton for nine seasons were:

Control . .	2·59 kantars per feddan.	NK	3·04 kantars per feddan.
PK . .	2·71 ,,	NP	3·07 ,,
NPK . .	3·04 ,,	N	3·07 ,,

N = Sulphate of ammonia, 200 rotls per feddan.
P = Superphosphate, 300 rotls per feddan.
K = Sulphate of potash, 150 rotls per feddan.

The only significant effect on yield is from added nitrogen, although in season 1942/3 it was noted that the crop was significantly earlier as the result of added phosphate.

Added in much larger quantity sulphate of potash gave a significant increase in cotton yield in 1931/2, but this effect was due to chemical interaction with the soil clay and improvement of physical conditions:

Control . .	2·57 kantars per feddan.	N	3·48 kantars per feddan
K . . .	3·92 „	NK	4·21 „

K = Sulphate of potash, 2 tons per feddan.
N = Sulphate of ammonia, 400 rotls per feddan.

Residual effects after 3 years were negligible.

With wheat at Shambat, ordinary applications of P and K gave no significant response.

On the other hand, sugar beet showed a marked response to superphosphate as well as to nitrogen:

Control . .	4·02 tons per feddan.	P	5·34 tons per feddan.
N . . .	4·48 „	NP	5·84 „

N = Sulphate of ammonia, 300 rotls per feddan.
P = Superphosphate, 400 rotls per feddan.

In recent pot experiments with Gezira soil, lucerne has responded markedly to phosphate.

Since phosphate is lacking in many parts of Africa it may well be that it is so in some parts of the Sudan, more particularly perhaps on the acid soils of the south where, even if not lacking, it may not be easily available.

Manurial Earths

In many parts of the world, notably India, the earth surrounding villages becomes impregnated with nitrates owing to the nitrification of excreta and other organic matters under a climate suitable also for accumulation. In Egypt the mounds or remains of old villages are used as a top-dressing, called 'sebākh kufri', for vegetables and certain crops such as wheat. Earths of other origin are also used, viz. 'tafla', a nitrate-bearing clay from desert hills in upper Egypt, and 'marōq', from uncultivated land between the river and the tafla-bearing hills and probably formed by surface wash from the hills.

Various samples from within the Sudan have been examined, but the nature of origin has seldom been stated. As in Egypt the value of such earths is dependent on the content of easily available nitrogen as nitrate, modified by the amount of soluble salts which sometimes reach high figures and will cause deterioration on any but the best drained soils. The average content of *nitrate*, expressed as sodium nitrate, in 32 samples from various parts is 0·9 per cent. which compares with 'sebākh kufri' in Egypt; but individual figures vary from 0·004 per cent. to 6·10 per cent. Variations within a limited area and with depth are great.

Of interest are so-called 'tundub' manures which are collected from near the roots of 'tundub' (*Capparis decidua* Pax.) growing on sandhills. Two samples indicate small content of nitrate (0·2 per cent. as sodium salt). The reason for their supposed usefulness is unknown; Andrews suggests that the 'tundub' bushes provide the only shade on sandhills for goats and sheep which shelter under them during the heat of the day.

At Kerma Basin, on land which is a little higher than flood level, salts are brought to the surface and used. A sample of surface scrapings contained the equivalent of 3·1 per cent. sodium nitrate but much other salt in addition.

As in Egypt manurial eárths are used for top-dressing of vegetables such as onion and of crops such as wheat. Cheap artificials will no doubt gradually displace use of these earths, of which the poorer qualities are worth very little indeed in terms of nitrogen.

Sesame Cake

Sesame (*Sesamum orientale* L., Arabic 'simsim') is one of the principal Sudan crops. The seed contains about 51 per cent. oil and 4·8 nitrogen: much is pressed locally, either in native camel-driven 'asāra' or in machine power-presses. The residue or cake produced varies in nitrogen and oil content partly owing to dirt in the original seed. The average of about 30 samples shows: oil 13·2 per cent., nitrogen 6·6 per cent. The cake is known locally as 'ombāz'.

Relative to ammonium sulphate it has rather less than one-third the content of nitrogen. Comparative trials in six seasons on moderately good land have shown that, applied on the basis of nitrogen content, it is as efficient as ammonium sulphate to increase cotton yields. At Hashāba, on the White Nile, the results for one season indicated, however, that on bad land application had a depressing effect on cotton yield, whereas on fair to moderate land there was the expected good response. The reason is not known, and the results must be taken with reserve.

In the above field experiments at the Gezira Research Farm the cake was ploughed in at the end of the dry season, about 2 or 3 months before sowing of cotton. In view of the limited rainfall, decomposition of the cake must have been relatively rapid, and this has been confirmed by laboratory tests. On alkaline soils some loss of ammonia has been detected if the cake is not covered, a practice desirable in any case to accelerate decomposition.

In general, the cake if not exported is mainly fed to cattle; whether the manure is utilized for crops is a matter of luck. As utilization becomes more systematic it will have to be decided whether it is possible and profitable to apply it to the land as animal residues.

Cotton Seed

The production of cotton seed in the Sudan is large; the bulk of this—from the Gezira, Gash, and Tokar areas—is exported or used for sowing. Because of high cost of transport the seed in the Nuba Mountains and equatorial areas is used as fuel for ginneries, pressed for oil, fed to cattle near by, or destroyed. Since the crying need of the soil in much of the country is nitrogen and since cotton-seed meal is a nitrogenous fertilizer of recognized value, the possibilities of extensive local pressing with export of surplus oil have not been forgotten.

The average content of oil in the seed is about 22 per cent. and of nitrogen rather less than 3 per cent. The crop in 1939 was over 120,000 tons, and therefore contained some 3,600 tons of nitrogen, equivalent to 17,000

tons of sulphate of ammonia. On decortication and pressing a material is obtained which contains over 6 per cent. of nitrogen and some residual oil. Modern methods of extraction can reduce the oil to a very low figure.

Two experiments covering eight seasons from 1933, comparing cotton-seed cakes or meal (decorticated and undecorticated) against the equivalent quantity of sulphate of ammonia as regards nitrogen, have shown equal cotton yields (see Chapter XX). The cake or meal was ploughed in 2 or 3 months before sowing and received some rain plus a pre-watering.

Although dura responds there is insufficient evidence for comparisons.

Cakes and similar materials must be covered, slightly at least, on more highly alkaline soils, not only to keep them as moist as possible for decomposition but also to prevent loss of ammonia which has been shown experimentally to take place when uncovered. Again, laboratory experiments show that the rate of nitrification increases as the nitrogen level of the product is raised by decortication and by pressing.

During one stage of the Second World War the accumulation of large stocks of cotton seed was expected and urgent experiments—both on a small and on a large scale—were carried out on the use of *raw* seed. Results were conflicting. Under post-war conditions wastage of oil must be kept to a minimum, and use of raw seed as a fertilizer is to be deprecated.

On the acid soils of the southern Sudan cotton-seed products may have an added value from the content not only of phosphate and of potash but also of bases. In the irrigated areas of the north there is no known deficiency of these minerals for the major crops, and in any case the irrigation water adds quite considerable quantities.

Farmyard Manure

The systematic use of animal manure is associated with mixed farming and is a very complex question. The Sudan, with its vast grazing-grounds in areas where rainfall is sufficient to produce growth of grasses, supports, where tsetse-fly is non-existent, very large numbers of cattle, sheep, goats, camels, and donkeys apart from the indigenous game. In addition there are the irrigated areas where a limited amount of fodder is available.

In rainfall areas some tribes are purely pastoral and nomadic; many cultivate crops in addition to maintenance of cattle and other animals. In the latter cases where land is not limited, shifting cultivation is practised. Yet, although there are cases where the land is insufficient for shifting cultivation, instances of any systematic use of animal manure are few. One has been described by J. M. Stubbs and C. G. T. Morison,[1] and by J. D. Tothill, and refers to the western Dinkas.

The Dinkas are a large cattle-owning and cultivating tribe living in the southern Sudan at the fringe of the semi-permanent swamps. During the wet season the low land is flooded, and the people with their cattle move to the higher land which is not only cultivated but also provides grazing for the animals; during the dry season they move back to the low land with its grass cover. The cultivated land lies in patches, rather like islands, between the lowest and the highest; it is of limited extent, but has been

[1] See 'Land and Agriculture of the Western Dinka', Stubbs and Morison, *Sudan Notes and Records*, xxi, p. 251, 1938.

kept in good heart by the following excellent system of mixed farming. The cattle during their annual migration to higher grounds at sowing time, after grazing during the day on the fresh growth of grass on low land near the villages, are closely tethered at night on the land due to be sown. The interesting and most unusual method of tethering the animals, each to a stake, for about three nights in succession is employed. The stakes are about 6 to 8 ft. apart. By the end of the third night the ground has been given a liberal supply of urine and a heavy application of manure, and is then sown. The cattle are then tethered on other land to be cultivated and finally when sowing is finished the cattle move to still higher grazing grounds. The same method is employed, but for various reasons less generally, on the return migration of the cattle towards the lowest ground. This highly developed and intelligent system is far in advance of what is generally found in tropical Africa; and offers possibilities in certain other parts of the Sudan.[1]

In the irrigated areas of the Gezira and of the White Nile little or no systematic use is made of animals to manure land, and it is more a matter of luck if manure is utilized efficiently, or wasted—perhaps on a crop of weeds. In the irrigated riverain areas of the northern Sudan appreciable use is made of manure from sites near homesteads where animals are tethered during the night; it is mainly used on wheat. In the Dongola area of the northern Sudan during 1943 the practice of tethering on land to be cultivated instead of near houses is reported to have increased noticeably.

At the Gezira Research Farm experiments have been carried out to test on cotton the value of manure, chiefly that produced by sheep folded on the land in the 7 months preceding sowing and fed with a known weight of dura stalk and grain to which was sometimes added sesame cake or cotton cake or cotton seed. There is no information on the net uptake of food; analyses of fodder were not made but, using average figures, estimates can be made of the increase in yield per rotl of nitrogen in the food:

Rotation	*Seasons*	*Rotls N per feddan in food*	*Yields of seed cotton in k.p.f.*		*Increase by manuring in rotls seed cotton per rotl of N*
			Control	*Manured*	
Continuous cotton .	7	15	1·28	1·77	10·3
C–D–F or C–D–R .	10	20	2·58	2·90	5·0
C–D–F or R–C–L–F or R (no cake)	7	60	4·38	5·21	4·4
Ditto (with cake) .	7	120	4·38	5·79	3·7

C = Cotton. D = Dura (Sorghum). F = cultivated uncropped land, i.e. fallow. L = 'Lubia' (*Dolichos lablab* Linn.). R = uncultivated uncropped land, i.e. resting.

The increases are variable but compare well with those given by sulphate of ammonia (p. 689). As regards cakes data are unavailable to show whether it is more profitable to apply them direct to the land or

[1] This practice is also referred to by Hewison and by Burnett at pages 652 and 294.—*Editor.*

indirectly as manure. In terms of immediate increases in cotton yield alone, there is a little evidence to favour direct application (Chapter XX); but there are many aspects to this important question, and much further work is necessary.

A recent experiment used the technique of the western Dinkas, described earlier. Bulls were tethered for three nights on land one or two months before sowing of cotton, (*a*) feeding *in situ*, and (*b*) after feeding outside, in both cases on an unlimited ration. Increases in yield of the succeeding cotton were appreciable.

(*a*)	Control . .	3·09 kantars per feddan	(100)
	Manured . .	4·24 ,,	(137)
(*b*)	Control . .	3·83 kantars per feddan	(100)
	Manured . .	5·18 ,,	(135)

The above experiments relate to manuring a few months before cotton sowing. The rainfall is sufficient to start decomposition of the manure without appreciable loss by weeds, and work on the continuous cotton plot has shown that nitrification is rapid.

Although manuring was most efficient on continuous cotton, the rotation is not practicable. Nevertheless, even with the lower return in the more open rotations the net return from the manure of animals in the irrigated Gezira, if properly used, could be considerable. The calculated return from over 100,000 feddans of dura stalks alone is estimated at approximately 6 million rotls of seed cotton worth, say, £E.60,000, and in addition there are nearly 40,000 acres of *Dolichos* which should almost double the figure. It must be emphasized that, unless applied to land due for crop and kept under fallow,[1] much of the value of the manure may be lost to weeds.

Analyses of the solid excrements of cattle and sheep have shown nitrogen contents, on a moisture-free basis, of 1·43 per cent. and 1·57 per cent. respectively. These figures are rather below those cited in the literature.

In conclusion, animal manure is, as expected, of very definite value in the Sudan; and animals should be utilized as efficiently as possible. A necessary condition in the irrigated area is that the holding of a cultivator must be compact to enable easy removal of fodder to the correct place. This condition is met in the riverain areas.

Green Manuring and Cover Crops

In many parts of the world special crops, often leguminous, are grown and ploughed in to improve the physical and chemical status of the soil. The only controlled experiments here have been carried out at Medani on heavy alkaline soil under irrigation, using *Dolichos lablab* Linn. (Arabic 'lubia') and *Crotalaria juncea* Linn. (Sunn Hemp) in a three-course rotation cotton–resting–legume/*or* resting. With several irrigations after ploughing in, yields of cotton over five seasons approximated to those of 200 rotls per feddan of sulphate of ammonia.

Control . .	4·81 kantars per feddan	(100)
Green manure .	5·40 ,,	(112)
S. of A. . .	5·42 ,,	(113)

[1] Fallow means uncropped but cultivated land.

With less water results were not so favourable:

	Expt. 1	*Expt. 2*
Control	5·25 (100)	3·56 (100)
Green manure	5·48 (104)	3·84 (108)
S. of A.	6·09 (116)	..
No. of seasons	4	8

Presumably decomposition of the material, including more resistant roots, was less complete. This is borne out by a comparison of *Dolichos* grown one or two years respectively before cotton, and watered once after ploughing in:

Control	3·56 (100)
Cotton–rest–*Dolichos*	3·84 (108)
Cotton–*Dolichos*–rest	4·33 (122)

Over a long period on another plot it has been found that the nitrate level is very low while *Dolichos* is growing; it is only when the plant remains to decompose that benefit accrues, and this takes time in a dry climate with seasonal and limited rainfall unless irrigation water is applied to accelerate the process.

On the above results the value of green manuring in the Gezira is, at most, only equivalent to a moderate application of nitrogenous fertilizer; and on this basis the cost in cultivation, irrigation, and use of labour is uneconomic.[1]

Of more practical use is to graze the crop, grown 2 years before cotton, and allow the remains to rot:

	Expt. 1	*Expt. 2*
Cotton–rest–rest	3·56 (100)	4·24 (100)
Cotton–*Dolichos*–rest	4·10 (115)	4·57 (108)
No. of seasons	8	16

As the net uptake of food by the cattle and sheep used is not known, the economics of the rotation cannot be calculated. The value can probably be increased considerably by control of weeds in the resting season.

In practice the cultivators often collect a crop of seeds, and the remainder is grazed *in situ* or carted off. No data are available on the manurial value of these methods; as a cash crop, the seed can be very profitable. If the 'lubia' is carted for fodder, it should be fed in such a way that the animal manure is utilized systematically.

Various legumes are grown in other parts (Chapter XVI) for their seeds; and in some areas the residues are used as fodder. There is a limited amount of lucerne (*Medicago sativa* Linn.) or 'bersīm hegāzi', but not to be confused with 'bersīm' in Egypt which is *Trifolium alexandrinum* Linn.; and recently striking depressions in cotton growth have been noted when sowing soon after this crop. There is clearly very much to be learnt as regards efficient utilization of legumes in rotations. So long ago as 1911, Grieve stated for irrigated areas his belief that whenever a crop is harvested the land should be watered at once to rot the roots; although this

[1] It must be remembered, however, that milk in quantity is essential for the health of the people and that forage crops such as 'lubia' are necessary for its production.—*Editor*.

is not always possible, the fundamentals behind the belief need careful attention and study.

In those parts of the country where conditions favour a fairly luxuriant annual grass vegetation, a grass rotation is often employed. After cropping, the land is allowed to rest under a cycle of natural grasses until a recognized climax is reached. Under the best-known system the grasses are burnt just after the beginning of the rains, when the new grass has started to grow. Both old and new are destroyed, and weeding of the succeeding crop is minimized. It is not known whether the regeneration of soil fertility works via improvement of physical properties or of the chemical, presumably nitrogen, status. Sterilization by heating must also be borne in mind. This system is employed on moderately alkaline soils.

Composts

A few composts have been examined in the last few years. As regards nitrogen content averaged results are as follows, on a moisture-free basis:

Material	*No.*	*% N.*	*Notes*
1. Cotton seed . . .	5	1·51	2·9% N in original seed.
2. Sweet potato vine . .	1	0·74	1·08% N in original material.
3. Cotton	1	1·05	. .
4. Town waste . . .	1	0·31	Khartoum house refuse.
5. Miscellaneous . .	9	0·54	Samples from Indore compost pits at Damer. C 4·8%; C/N 8·9; K_2O 0·15%.

A controlled experiment with materials 1 and 2 on cotton showed no response, but the applications were late. An earlier experiment using 20 tons rotted plant refuse per feddan showed a 25 per cent. increase in cotton yield, but the amount of nitrogen added is not known.

Of interest is a sample of compost prepared from 'sudd' (large masses of vegetal matter in the Upper Nile swamps). The sample, prepared by a secret process in England, contained: N 2·0 per cent., P_2O_5 1·0 per cent., K_2O 2·4 per cent., figures roughly four times those of FYM. Cost of transport alone would prevent its use in the districts where fertilizer is required.

At Khartoum North, canal weeds used as a fertilizer gave disappointing results.

Clearly it is unfair to draw conclusions on limited data for material which has undoubted value if the conditions of use are understood. The extreme southern Sudan with no cattle, ample vegetation, and considerable rainfall offers a virgin and potentially profitable field of work. In the north suitable waste materials are less and climatic conditions are difficult.

Trace Elements

At various times a range of minerals (including iron, manganese, copper and boron) has been tested with cotton on Gezira soil, either by direct application to the soil or by spraying the plants. There has been no significant effect.

Soil Improvers

On highly alkaline soils in which water movement is limited, the application of substances such as gypsum is often a remedy. Combined with copious watering, the salts, mainly of sodium, which result from chemical reaction between soil and improver are removed by increased downward movement of water to the water table or to drainage ditches. The improver can be called a fertilizer.

Many experiments have been carried out on the highly alkaline Gezira soil using gypsum, potassium sulphate, sulphur, ferrous sulphate, and calcium chloride; normal applications have been 1, 2, or 4 tons per feddan of gypsum, or its equivalent. Increases in yield of cotton have varied from nil to the equivalent of a heavy application of sulphate of ammonia. Residual effects have, however, been small. It is now clear that permanent alteration of the deep and heavy clay profile containing notable quantities of sodium—exchangeable and soluble—can only be contemplated by large applications of improver combined with drains. On a large scale this is economically impossible. Any temporary good effect is probably due to transient surface, flocculation, and increased nitrate level. From examination of nitrates in a continuous cotton rotation experiment to which gypsum was added it is clear that the variable responses noted above may be due to a varying extent of interaction of improver and soil before sowing.

Night Soils

The sanitation system of the Sudan is primitive. Pits or buckets, together with earth or sand, are used in or near the towns, and after a period for decomposition the resultant night soil is often used as fertilizer. The nitrogen is partly in an organic form, partly nitrate; the total content of a few samples varied from 0·08 to 0·54 per cent. (compared with 21·3 per cent. in sulphate of ammonia). Phosphate and potash are also present.

Miscellaneous

Samples of pigeon manure contained 3·1 per cent. N and 2·3 per cent. P_2O_5, bat manure 7·1 per cent. N and 2·1 per cent. P_2O_5, and so-called 'dōm' peat (factory residue from use of kernels of seeds of *Hyphaene thebaica* Mart. in manufacture of buttons) 0·5 per cent. N. All are relatively scarce.

A sample of earthnut oilcake (*Arachis hypogaea* Linn.) had 5·6 per cent. oil and 8·0 per cent. N. This crop, although it grows well on light soils, is limited in amount and the nuts are normally eaten without crushing.

SECTION III

CHAPTERS DEALING WITH PROVINCE AGRICULTURE

CHAPTER XXV

KASSALA PROVINCE

By E. MACKINNON,[1] 4 N, B.SC. (Agric.), *Asst. Director of Agriculture*

'So 'eres *to* you Fuzzy-Wuzzy, at your 'ome in the Soudan;
You're a pore benighted 'eathen but a first-class fightin' man'
RUDYARD KIPLING: *Fuzzy Wuzzy.*

GENERAL REMARKS

Area, Population, Administration, &c. (as at 1940)

Kassala Province

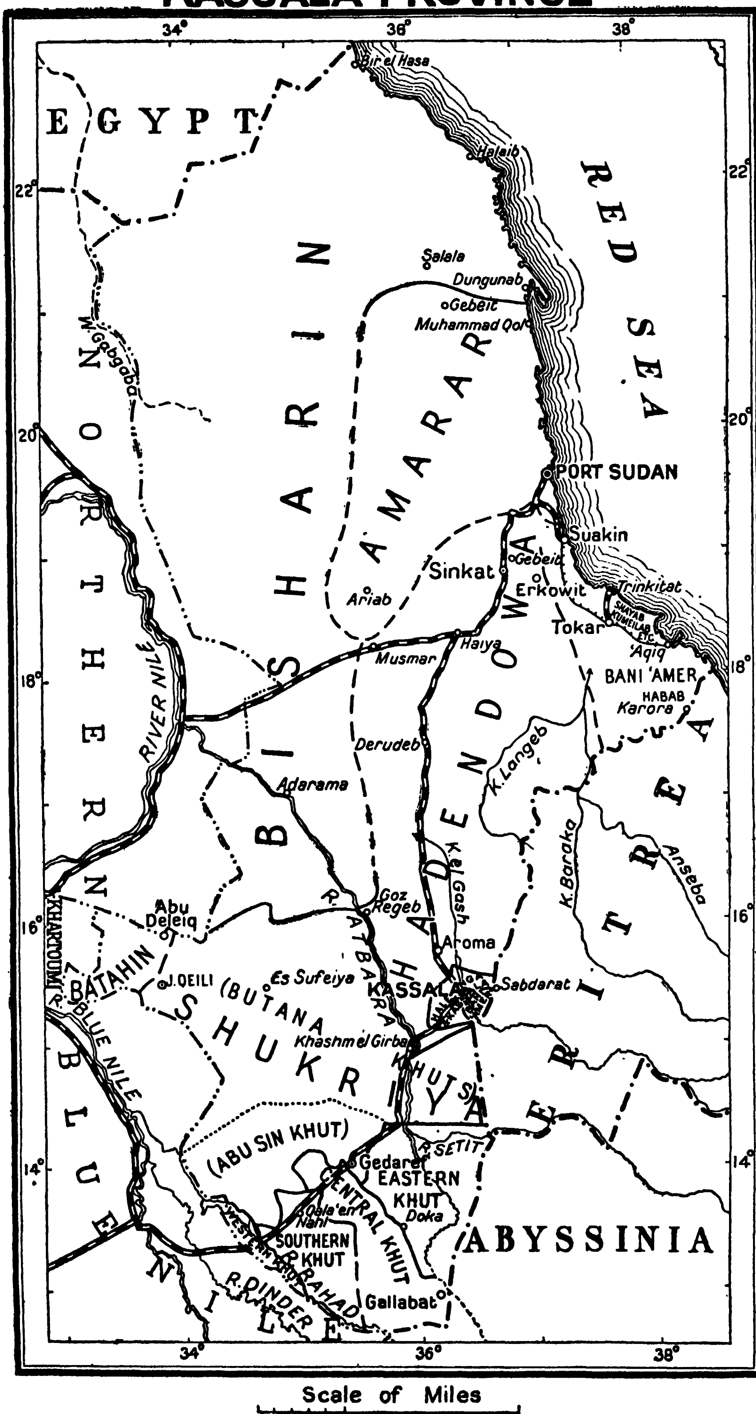
District	*Area square miles*	*Population*	*Government stations*
Southern .	31,705	147,600	Gedaref (District H.Q.). Gallabat (Military Post). Abu Deleig (Sub-district H.Q.).
Kassala . .	700	56,835	Kassala (District H.Q.).
Beja . .	96,045	137,000	Sinkat (District H.Q.). Aroma (Govt. Station). Police posts: Derudeb, Goz Regeb, Musmar, Gebeit, Salala, Halaib.
Red Sea . .	6,000	80,543	Port Sudan (District H.Q.). Tokar (Sub-district). Suakin (Govt. Station). Police posts: Aqiq, Trinkitat, Karora.
Totals .	134,450	421,978	..

The province headquarters are at Kassala, a town of some 30,000 inhabitants, but the administration is moved to Sinkat during the summer months. The Port Sudan–Suakin (Red Sea) district is under the charge of a Commissioner. The Governor-General often moves his offices and staff to Erkowit, a small hill-station, during the hot months of the year.

In the earlier days of the administration Suakin, Abu Deleig (Butana), Khashm el Girba (Atbara R.), and Gallabat (Abyssinian frontier) were

[1] I wish to acknowledge considerable help from members of the Political Service, Irrigation Dept., and the Dept. of Agriculture and Forests in the preparation of this chapter. Especially I wish to acknowledge the assistance received from W. C. Young, Manager of the Gash Board, R. J. Smith, Irrigation Dept., and J. Smith, Chief Conservator of Forests. E.M.

MAP OF
KASSALA PROVINCE



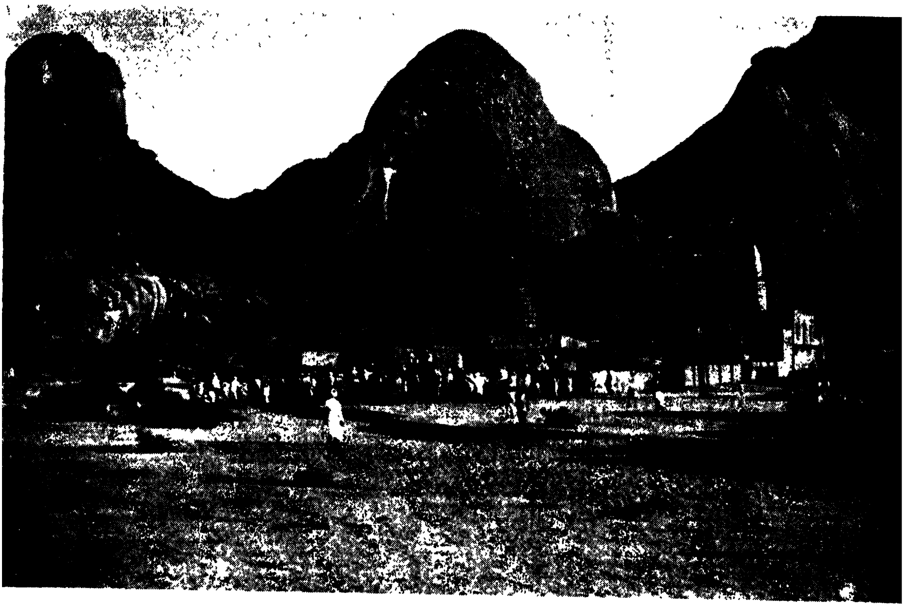


FIG. 277. Khatmia village: at the base of Jebel Kassala (*photo G. J. Fleming*).

FIG. 278. Red Sea Hills near Erkowit, showing gullying and typical scenery (*photo F. Crowther*).

sub-district headquarters with a resident British Political Officer. Gallabat figured in the fighting during the 1940–1 campaigns; it has not since been reconstructed, and a new station has been opened at Basunda, some 20 miles farther west. Dungunab, north of Port Sudan, was the site of a pearl-shell fishery. Flamingo Bay, near Port Sudan, is now the centre for the mother-of-pearl, trocas shell, and bêche-de-mer industry.

Small gold-mines are being worked at Gebeit and Oyo in the Red Sea Hills, north of the railway line.

FIG. 279. Jebel Erbab from near the rest camp in the Red Sea Hills at Erkowit (*photo H. W. B. Barlow*).

Historical Summary

During the Mahdist rebellion the Suakin–Tokar area was the scene of much skirmishing and fighting during 1884–5. Tokar fell to Mahdist forces under Osman Digna in 1884 and was not finally retaken till 1891. Kassala was invested by Mahdist troops in 1883 and capitulated to them in 1885. This town was occupied by Italian forces between 1894 and 1897 and relieved by Anglo-Egyptian troops on Christmas Day 1897. The southern portion of the province was severely depopulated during the Mahdist régime, as a result of war, famine, and disease. The second occupation of Kassala by the Italians in 1940 lasted for only a few months. Suakin is the only town of any antiquity; the foundation of Kassala dates from 1840 and Port Sudan from 1905 only.

The Atbara–Suakin railway was completed in 1905 and a branch to Port Sudan constructed the following year. The Haiya–Kassala section of the line was begun in 1923 and reached Kassala in early 1924. The extension to Sennar via Gedaref was completed in sections and was finally opened for traffic in 1929.

The present province was formed by the amalgamation of the old provinces of Kassala, Red Sea, and parts of Berber. Since Port Sudan

became the main harbour the trade and importance of Suakin have slowly and steadily declined, though it still deals with much of the pilgrim traffic to Mecca.

Physical Features

The northern part of the province is mainly desert with rocky outcrops. From a narrow coastal plain on the east the land climbs rapidly to a chain

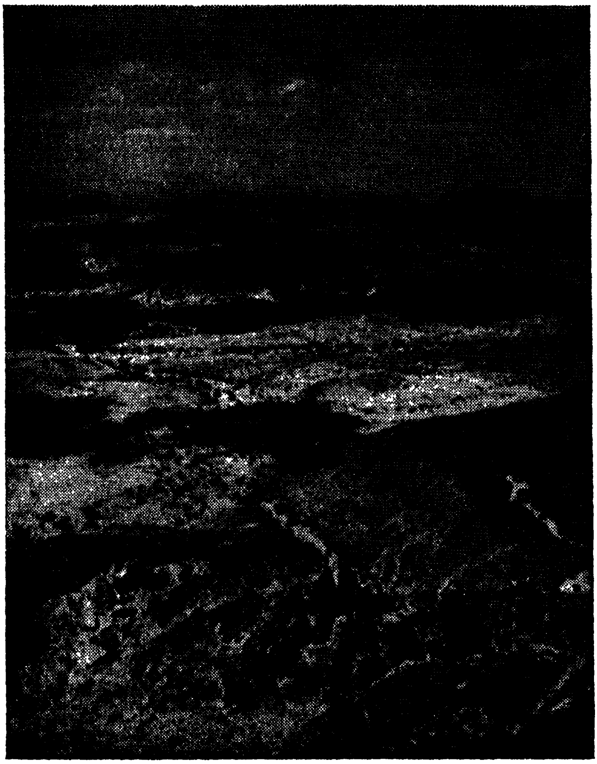


FIG. 280. The Red Sea Hills seen from the top of Jebel Erbab. The rainfall is here insufficient for agriculture (*photo H. W. B. Barlow*).

of mountains extending from Egypt to Eritrea. These are stark masses of rock, with little or no vegetation, except in the valleys, until the railway line is reached. From this point southwards the rainfall increases towards the Eritrean frontier, and the hills become more clothed with thorn-scrub and other trees and bushes. Following the winter rains seasonal spates occur (Fig. 281) and a flush of grass provides grazing for the southern nomadic tribes.

From the watershed the land drops more gradually to the Nile valley. The water channels running to the east are mainly dry river-beds, carrying storm-water on to the plain. Perennial water is, however, found in some places, e.g. near Erkowit and in Khor Arbaat which provides Port Sudan

with its water-supply, and some of the streams near the Eritrean border flow for a few months before drying up.

The main river is the Atbara, lying well below the plain level with a marked band of eroded water channels, known as the 'kerrib', cutting through from plain to valley. Its main tributaries are the Bahr es Salaam and the Setit, both springing from the Ethiopian highlands, from which the Atbara itself also originates. The Atbara in flood is a deep and imposing river, but it dries out to a series of pools, often of large size, during the period between the rains.

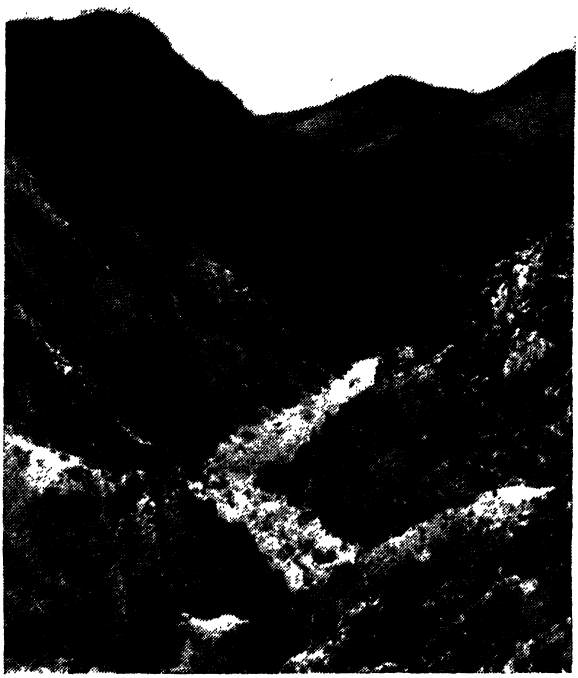


FIG. 281. Khor Gwab in spate at Erkowit. This happens very seldom (*photo H. W. B. Barlow*).

Two seasonal rivers which are of great importance (from the agricultural point of view) are the Gash (Mareb) and the Baraka, both of which originate in Eritrea. The Butana plain, west of the Atbara, is generally featureless; in the southern part of the province isolated hills occur which increase and coalesce as the Abyssinian foothills are reached.

The southern boundary of the province is close to the Rahad, which flows into the Blue Nile near Wad Medani.

Rainfall and Vegetation

From the Egyptian frontier to the railway line the rainfall is sparse and

The Rashaida are mainly interested in breeding a heavy type of weight-carrying camel, usually brown or reddish in colour. Many are sold to Egypt to provide for the requirements of the camel-meat market.

The southern Bisharin, sited along both banks of the Atbara, live in conditions more favoured by river and rainfall and, in consequence, are better provided with flocks and herds in addition to camels. The coastal region lying between Tokar and the Eritrean frontier also affords better grazing facilities and forms the main winter and spring feeding for the Sudan section of the Bani-Amer. The southern Butana plain trends from a 4-in. annual rainfall into the zone of rain cultivation proper. It is occupied by the Shukria, Batahin, and Lahawin tribes, who breed both a riding and a baggage type of camel and have large flocks and herds in addition.

In general it may be said that the more hardy goat and camel are found in the drier part of the province and cattle and sheep increase in numbers and importance as water-supplies and grazing improve with the rainfall. Sheep, however, do not thrive on the heavy black soils of Gedaref.

The Tokar Delta

General Description

The Tokar Delta (see Fig. 249 on p. 622) is formed by the alluvial deposits laid down by the flood-waters of the Baraka river. The Baraka rises in the Eritrean highlands south of Keren; in Eritrea itself there are two main branches, the Baraka (Barca in Italian maps) and the Anseba. A further feeder is the Khor Langeb, which rises in the hilly region of the Sudan lying to the north of the Gash Delta. In all these streams the flow is limited to violent spates produced by heavy storms during the rainy season. From October to June, or even July, they are dry.

The total catchment of the Baraka and its tributaries amounts to some 45,000 square kilometres, consisting chiefly of rough mountainous country. After its junction with the Langeb the Baraka has a wide sandy channel, with a bed-slope of some 150 cm. per km. Some 33 km. south-east of Tokar the river is constricted into a narrow gorge at Shiddin rock; downstream of the rock the bed-slope averages about 100 cm. per km. After a further 6 km. the river enters the coastal plain and starts to divide: there are three main branches which originally carried water to the western, central and eastern parts of the delta respectively, but for many years the trend of the water has been consistently to the eastern side. From these main distributaries the water spreads over the surface of the land by a network of shallower subsidiary branches which divide, subdivide, and occasionally rejoin to form deeper channels draining to the sea.

The delta itself lies some 90 km. south of Suakin and forms a roughly equilateral triangle with sides of 70 km. Demarcation of this area has not been completed, and the total land included amounts to some 386,000 feddans.

The unit of division is the 'murabba'' (square) of 160 feddans measuring 800 × 840 metres. The delta is divided into named 'hōd' (basins) comprising from 15 to 65 'murabba'. From the point where the Baraka starts

FIG. 283. Red Sea Hills near Erkowit. Candelabra tree (*Euphorbia erythraeae* N. E. Br.) in foreground (*photo F. Crowther*).

FIG. 284. Dragon tree (*Dracaena ombet* Kotschy and Peyr) and Candelabra tree (*Euphorbia erythraeae* N. E. Br.) (*photo H. W. B. Barlow*).

FIG. 285. Shukria camel, at Khashm et Girba, with 'utta' and trappings. The size of the animal should be noted, as the girl in the foreground is over 5 ft. 8 in. tall (*photo G. J. Fleming*).

FIG. 286. River Atbara: Rashaida Arabs watering their animals (*photo G. J. Fleming*).

to spread the fall of the land decreases gradually, until the salt-flats near the sea are reached; here the land is practically level. Two major factors affect the general levels of the land. These are, firstly, the amount of silt deposited by the river as it spreads over the land and, secondly, the wind-scour and dune-building resulting from the action of the fierce and prolonged winds that are so typical of the district. Both of these factors are discussed more fully later.

Soil Types

The river carries an enormous amount of silt in suspension and, wherever the flow is checked or slowed down, silt is deposited on the land. The coarser particles are thrown down first, so the southern 'hōd' are largely composed of the coarser and more sandy types of soil.

A chain of dunes ('debba') extends along both sides of the delta; although undergoing marked changes annually, owing to wind or water action, they persist as a regular feature of the general landscape. Further irregular groups of 'debba' form natural barriers to the north-east and check the flow of the water to the sea, except in those places where channels have forced their way through the obstruction. These 'debba' are sometimes composed of sand, but are usually formed of fine particles of weathered silt. With the exception of the more southerly sandy portion of the delta, the bulk of the soil consists of fine buff-coloured alluvial silt laid down by the river. The clay-content is high, but the soil itself is friable, is very fertile when weathered, retains moisture to a marked degree, and allows for deep root penetration. The well-flooded land can thus carry a cotton crop from September till May or June with no extra moisture to assist the growth of the plant, beyond that provided by the winter rains (generally light) and the dews that occur during the cool and cloudy winter months.

The underlying soil often varies. On the fringes of the delta it may consist of sand or gravel. Near the sea the subsoil may be too impregnated with salt to allow for satisfactory plant growth. In many places alternating layers of sand and silt may be found. All these varying soil types are potentially cultivable. The thin soils may have fresh overlays of silt deposited on them, thereby increasing the depth of the fertile profile. The dunes may be swept away by flood or wind action and deposited elsewhere. Even the salty land improves, owing to the leaching action of the flood waters and to deposits of new silt. Land which was too salty to grow anything in 1921 was carrying an excellent crop of cotton only 2 years later.

River Records and Discharges

The Baraka is a mountain torrent whose flow is dependent on the rainfalls in the Eritrean highlands. There are, therefore, large variations from year to year in the volume of water discharged on to the Tokar plain, in the duration of the flow, and in the incidence of flushes. A typical flood consists of a series of flushes which may flow for a few hours only, or persist for several days; in the intervals the river may dry up completely. The flood season usually extends over the period mid-July to mid-

September, with the bulk of the spates occurring during August. Three typical flood-maps of poor, medium, and large floods are shown in Fig. 249. A good flood may irrigate some 125,000 feddans, a poor one only 25,000. Discharges and observations have been made during three seasons only, and the records of these are shown below:

	1912	*1913*	*1920*
Total area flooded (feddans)	53,500	30,100	136,000 round figures.
Area sown cotton (feddans)	40,300	28,200	116,500 round figures.
Total discharge (millions of m.^{3})	209	205	968
Maximum discharge (m.^{3} per second)	477	753	1,129
Number of days of flow*	41	70	60
Number of important flushes	5	5	7
Maximum surface velocity (metres per second)	4·16	..	7·2

* Approximate: discharges not recorded after 8 September. Actually small flushes occurred till late October.

Silt in Suspension

A river's ability to carry silt in suspension is related to its velocity. In 1920 it was found that the surface velocity of the Baraka varied from 3 to 5·5 metres per second during big flushes, with a maximum of 7·2 metres per second (16 miles per hour). By comparison the average rate of flow of the main Nile in flood (in Egypt) is about 1·75 metres per second. The Baraka waters were then found to carry as much as 10·6 per cent. of their weight as suspended silt, or 46 times more than the main Nile in flood. It can thus be readily realized how the high silt-content and extremely irregular flow create difficulties in river control and prevent the use of irrigation methods which can be employed successfully elsewhere.

Irrigation Methods and Control of the Flood

A number of comprehensive reports on the Tokar Delta and the more efficient use of the waters of the Baraka have been written. The first of these was produced by Sir William Garstin, of the Egyptian Irrigation Service, who visited Tokar in 1892. Early recommendations visualized the division of the delta into a series of basins ('hōd') into which the water could be led. The basin system was subsequently condemned in view of further experience of the problems involved. The latest proposals are contained in a report published in 1923 by F. W. Cramer Roberts, also of the Egyptian Irrigation. In it he reviewed previous suggestions and attempts to utilize the waters of the Baraka more efficiently and put forward his own proposals in the light of experience gained after the exceptionally large flood of 1920. He recommended the division of the delta into four roughly equal sections, by the construction of three radial banks which converged to meet at a point some 15 km. south of Shiddin rock. These banks would be stone-pitched at the point of distribution. A temporary bank would be built annually across the lowest sector, so as to guide water into one of the two central areas. The earlier flushes would be discharged into the chosen sector and the flood-waters would be allowed to take their course unchecked, until the land had been sufficiently watered.

The temporary bank would then be cut and the later flushes would all go to the lowest sector, thereby gradually building up the land levels in this area. It was estimated that the capital costs required for this programme would be some £E.48,000, whilst annual expenditure on maintenance and control would cost a further £E.7,000.

These proposals have never been put in hand and it is unlikely that any major programme of works will be considered until the levels to the east have been raised considerably and the river again shows a tendency to swing to the centre or the west. Indeed, in the light of experience, it is somewhat doubtful if a complete system of permanent control works could ever be successfully operated and maintained.

Minor irrigation works have been employed with varying success over a long period of years; these consist of four main types:

(i) Banks across the direction of shallow flow to hold up the water, and so obtain more equal flooding.
(ii) Banks across the main river channel to divert the whole flow towards the centre of the delta.
(iii) Cuts from the main channel to lead the water into other distributaries.
(iv) Banks to close off drainage khors, or sea-banks to prevent the flood-waters from reaching the sea.

The first two methods are now regarded as unsound and their use has been discontinued for many years. The other two have been employed within more recent times. Banks to close off drainage channels and thus to prevent their extension by eating back towards the head of the delta feature in the annual works programme but, unless extensive, are liable to be outflanked by the spread of the flood.

Check levels are run across the delta from time to time, so as to record any marked changes in the land-slopes. From these it has been confirmed that the land to the east is still very low and that the building up of that side of the delta is proceeding more slowly than originally anticipated. Levels were originally checked every third year, but this work is now being carried out at intervals of six years.

Climate

Climatic conditions at Tokar have a very marked effect on the crops that are grown, and in the planning of the working year. The cotton season is brought to a close by the onset of the 'habūb' winds which usually start towards the end of May. These winds blow from a southerly to south-westerly direction for several months. They may persist for days on end without a lull and cover the delta with a dust-pall which effectively curbs all outdoor activities. Most of the Tokar inhabitants who can afford to do so quit the delta in search of purer air and pleasanter conditions. The force of the 'habūb' winds is the main factor in altering and rebuilding the dunes of the delta; these winds also bury or blow into the sea the cotton debris of the previous season, and so give the Tokar area a marked immunity from pests and diseases generally. With the onset of the Baraka floods a lull occurs which enables the sowing of the watered land to be completed

in comparative peace. From October onwards the 'hababai' winds begin: these blow from an easterly to north-easterly direction and they usually persist till the onset of the winter rains. They are hot dry winds and, though not so severe as the 'habūb', they can cause much damage to young crops by scorching them or by exposing their roots by wind-scour. Wind-breaks of dura and dukhn are, therefore, encouraged throughout the cotton area in order to reduce the damage by the 'hababai'. The cool north wind of winter brings with it rains, cloudy skies, and frequently heavy dews; with its advent cotton and other crops recover quickly from their previous buffetings.

The rainfall on the delta itself occurs during the winter and is generally light, but its effects are very marked; if heavy, it sometimes allows for the sowing of additional grain crops. Cool and cloudy conditions usually persist until about March and the maturation of the cotton crop is frequently delayed in consequence.

Records of rainfall (in millimetres) for two recent seasons and average figures are shown below:

Month:	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*Year*
1939–40	..	1·4	1·5	..	Tr.	28·6	9·3	4·9	3	1·8	Tr.	0·3	50·8
1940–1	Tr.	Tr.	0·6	Tr.	1·8	191·4	28·3	29·6	1	0·2	Tr.	2·5	255·4
28-year average 1913–40	2	4	2	..	10	17	10	21	4	1	2	5	78·0 (round figures)

Tr. = trace. The November 1940 rainfall is quite exceptional.

The Cultivating Season

It is probably most convenient to consider the cultivation of crops as from the time of the first land allotment. The land at Tokar is all Government owned and is leased on an annual basis to registered holders. The primary allotment of land is made before the advent of the flood by a Land Board. Assistance in a purely advisory capacity is given by the 'Meglis Ahli' (local Sudanese council). Old registrations of land are checked and confirmed and there is always a reserve of unallocated land kept in hand. After the floods have watered the delta a rapid check-up is made and unallocated land which has been watered is divided up, as far as possible, amongst those whose holdings have been missed by the flood. Cotton-seed is issued free to land-holders in well-watered areas and a cultivation grant, to assist crop establishment, is also made at this time. Holdings vary in size, and the full 'marabba' of 160 feddans is frequently allocated in plots of 40, 20, or 10 feddans; subletting by tenants often further reduces the individual holding. Formerly the land was allocated in large holdings (known as 'dimin') to tribal sheikhs and notables. From these large blocks of land, often extending to many thousands of feddans, they were supposed to satisfy the requirements of their followers and dependants. This system has worked reasonably well in the past, but it offers obvious opportunities for peculation on the part of the 'dimin' holders. From 1942 onwards it has been decided to make a steady reduction in the large holdings, the reduction to be gradual and spread over a series of years. The land that thus becomes available will be reallocated in smaller

holdings to individual cultivators. This will inevitably increase the number of registered holders, but it should go far to ensure a more equitable distribution.

Sowing begins as soon as possible, the receding waters being followed up as the land dries sufficiently. There is always a danger of the crops being washed out in some areas (owing to late flushes), but this risk has to be faced and early sowing helps to spread the available labour and to reduce costs.

The best land is reserved for cotton; the inferior soils and more lightly watered areas are usually sown with grain crops (dura and dukhn), but the sowing of limited belts of other crops is encouraged in the cotton areas, both to mark boundaries and to form wind-breaks against the 'hababai'.

The spacing adopted is usually 1 metre × 1 metre; a slab of new silt is turned up, a hole dug with the sowing-stick ('selūka') in the weathered silt below, and the seeds dropped in and covered. Resowing, if required, is done as soon as possible afterwards. The cotton is thinned out when about 4–5 weeks old and no subsequent operations are required, beyond keeping the crop free from weeds, until the cotton bolls start to open. The dura and dukhn belts are the first to be harvested and the cotton is picked and transported to Tokar as it matures. Cotton markets usually start about the end of February and remain open till May or sometimes June. The old cotton stalks are then cut out and burnt, along with other weeds, and the clean land awaits another revivifying flood.

Cotton is the main crop sown and invariably occupies the bulk of the area; grain crops, 'ads sudani' (*Cajanus cajan* (L.) Millsp.), and a few indigenous vegetables are also grown, but pressure has usually to be exerted to limit the sowing of cotton on unsuitable land, rather than the reverse process.

The Cotton Crop

It is not proposed to trace the earlier history of cotton growing at Tokar in this short summary. Cotton was first introduced into Tokar about 1867 by Ahmed Mumtaz Pasha, the then Governor of Suakin. Since the re-establishment of settled conditions in the Sudan, following the 1896–8 campaign, the cotton crop has gone steadily ahead; annual fluctuations in the areas sown and the gross yields obtained naturally occur, but these are mainly due to the vagaries of the flood.

In early days Afifi and Asili cottons were mainly grown, but small trials with American upland cottons were made from time to time. American types gave very good yields and at one time the growing of American cottons exclusively was seriously considered. Sakel was first grown in 1920, and from 1921 to 1934 formed the main crop. In the 1934–5 season X1530 cotton was introduced on a small scale, as leaf curl was seriously affecting the yield of the more susceptible Sakel by then. From 1935 onwards X1530 or similar cottons have formed the bulk of the main crop; these are Sakel selections with a marked resistance to leaf curl. Details of cropping and cotton production for fifteen recent seasons are shown in an appendix (p. 734).

in three instalments of 20 P.T. each, at the times of sowing, weeding, and picking the crop. To cover this increased outlay the Government percentage of the cotton crop was raised from 25 to 30 per cent. of its value.

Banking facilities are provided in Tokar during the cotton-market season to finance the large amounts involved in the purchase and forwarding of the crop.

Pests and Diseases

Blackarm (*Xanthomonas malvacearum* (E.F. Sm.) Dowson) is practically unknown in Tokar, as the local climatic conditions inhibit its development and spread. Leaf curl, a virus disease carried by the white-fly (*Bemisia gossypiperda* M. & L.), was formerly unknown, but became so severe in 1935 that a change was made to the resistant X1730 type of cotton. Cotton aphis (*Aphis gossypii* Glover) often causes severe damage, especially in the damp cloudy weather of February and March. The sticky exudation of these insects not only covers the leaves and fouls the lint of the cotton plant but frequently forms a suitable base for the development of a sooty mould (*Cladosporium*) which further discolours the lint.

Bollworms of the various types are usually found, but only to a small degree; the most serious damage is usually that caused by the pink bollworm (*Platyedra gossypiella* Saunders). The Tokar vicinity, during the winter months, often forms a breeding-ground for the desert locust (*Schistocerca gregaria* Forsk.) and damage by both hoppers and flying swarms has occurred from time to time, though this is mainly confined to grain crops. Latterly these outbreaks have been taken in hand at an early stage and suppressed before any serious damage by, or flighting of, matured hoppers could occur.

The grain crops (dura and dukhn) are often affected by the stemborer (*Sesamia cretica* Led.), with resultant loss of crop, as well as by the indigenous types of smut that are prevalent in the Sudan. But, taken as a whole, the various pests and diseases that affect both cotton and other crops are generally less serious in their effects at Tokar than elsewhere in the main producing centres of the country.

The most serious and persistent weeds are sedges (*Cyperus* spp., mainly *C. rotundus* Linn.); other weeds are mainly annuals which can be eliminated by thorough hoeing.

The Gash Delta

General and Historical

The delta (see Fig. 248 on p. 620) consists mainly of alluvial soil deposited by the Gash which rises in the Eritrean highlands south of Asmara; the river is known as the Mareb in its upper reaches.

The annual flood reaches Kassala, in a normal year, between 20 June and 10 July; the average flow continues over a period of about 3 months.

The soil types encountered are not so uniform as at Tokar. There are large stretches of fine alluvial silt, known locally as 'lebbād', which are very similar to the best Tokar soils in appearance, texture, and value. In various places sandy patches with a sparse growth of vegetation occur;

FIG. 287. The River Gash in flood near Kassala (*photo G. J. Fleming*).

FIG. 288. Gash delta: Saidi (Egyptian) labourers digging the original Magauda Canal in 1924 (*photo G. J. Fleming*).

FIG. 289. Gash delta: cotton growing in a tamarisk clearing (*photo E. Mackinnon*).

FIG. 290. Gash delta: bringing in cotton by camel (*photo G. J. Fleming*).

these are termed 'mashandow' and frequently form well-centres. Large stretches of black soil ('bādōb'), which have a high clay-content and which crack on drying, are found—especially to the north of the delta. The 'lebbād' and 'bādōb' soils are found intermingled in greatly varying gradations. The irrigation permitted by the prolonged flow of the river, the general richness of the soils in the Gash Delta, and the situation of Kassala on the old trade-routes to Suakin and Massawa have contributed largely to the importance of the district. In bygone days the Kassala district was one of the main grain-producing centres and Gash duras were famed for their quality in Arabia and elsewhere.

Kassala town itself was founded in 1840; by 1882 it had become the most important place in the eastern Sudan with the exception of Khartoum, and being of considerable strategical importance it has changed hands on several occasions. In 1885 it was captured by Mahdist forces from the Egyptian garrison. Between 1894 and 1897 it was held by Italian forces which were withdrawn at the end of the latter year, on being relieved by Anglo-Egyptian forces detached from Kitchener's Army of the Nile. In 1940 it was again taken and held for a few months by Italian troops before Eritrea itself was invaded and captured by our forces.

The construction of a railway to Kassala was often mooted before the line was actually completed. Early proposals envisaged the route Suakin–Kassala and from thence down the Atbara river to Berber. A branch from the existing system was begun at Haiya in 1923, and railhead reached Kassala early in the following year. The line was subsequently extended southwards, via Gedāref, to join the main line from Khartoum to El Obeid at Sennar.

The growing of commercial types of cotton in the Gash Delta probably began about 1860 and the construction of a ginnery was planned as early as 1874. No serious attempt to expand this crop was made till 1918, and the first large canal, with head regulator and controlled off-takes, was not built until 1924. Since then the canal system has been largely extended to its present dimensions, with six main stations and a headquarters at Aroma. Irrigation works are discussed more fully under later headings.

The River Gash

General Description. From Gulsa (where the Gash enters the Sudan) to Kassala the river has a wide sandy bed, often more than a kilometre in width. Taking off from the west bank opposite Jebel Kassala is the Khor Kwenti; this is probably an old bed of the river, but the head is silted up and it now carries rain-water only, except in the highest spates. The possibility of using this channel to irrigate an area of some 20,000 feddans has been raised in the past, but the scheme was shelved in favour of developing the main delta. Some miles north of Kassala the Gash formerly divided into two main channels, the Eastern and Western Gash, but, for the last 25 years, the whole of the flow has followed the line of the Eastern Gash (v. Fig. 248).

Between the two main arms of the river is the Khor Salaam Aleikum which has been developed, within recent years, to supply water both for irrigation and to replenish the Gemman well-centre. North of Magaudo

the Eastern Gash has a narrow, tortuous channel and has so built up its bed that it commands the adjacent ground. It is, therefore, easily available for irrigation, particularly as in general the land slopes from east to west as well as from north to south. Protection banks are built in those places where the river shows a tendency to break away to the west.

Near Hadaliya the river again divided into two main channels, the Khor Awadai and the Khor Filik; of these only the former is now in operation in normal floods, the latter depending on overflow from high peaks. The irrigation canals take off directly from the main eastern channel, and the maintenance of flow in this channel now forms the major engineering problem in the Gash.

North of Illibilli no controlled irrigation is possible at present but, in years of big flood, the watered land may extend well to the north of Amm Adam.

Flood records, taken at Kassala weir from 1907 to 1929, have shown he following variations: discharges are given in cubic metres of water.

Arrival of flood: earliest 10 June (1929); latest 18 July (1925).
Duration of flow: shortest 68 days (1913 and 1925); longest 109 days (1929).
Total discharge: minimum 137 million (1921); maximum 1,260 million (1929).
Average period of flow: 88 days (1907 to 1940).
Mean annual discharge: 483 million m^3.

Exceptionally early freshets, lasting a day or two, occur in May or June; the earliest recorded was in 1929, 25 April. A flow of 114 days occurred in 1935. Since 1923 discharges have been recorded at Magauda, and the main departures from the above figures are as follows (1923–40):

Total discharge: minimum 90 million (1925); maximum 965 million (1929).
Mean annual discharge: 403 million.

Silt in Suspension. Records of the amount of silt carried in suspension were taken in 1924, 1926, and 1939. The following maxima were obtained:

1924 Magauda 10,050 parts per million.
1926 Kassala 8,100 „ „ „
1939 Gemman (flush) 15,500 parts per million.
„ Tendelai (flush) 12,400 „ „ „
„ Kassala 6,500 parts per million.

Comparative figures of silt in suspension for the Nile in flood, at the point of entering Egypt, are:

Maximum solids: 4,000 parts per million.
Average Aug.–Oct.: 1,500 parts per million.

The 'balagh' areas act as filters in the Gash and remove large quantities of the silt in suspension (from 70–95 per cent.). Records therefore show much variation in different parts of the delta.

The largest area of irrigable land flooded (in 1929) was about 85,000 feddans in the demarcated portion, plus some 25,000 feddans flooded by spill to the north. The present policy aims at irrigating a cotton area of some 35,000 feddans annually, and flooded land in excess of this is either sown with dura or utilized for grazing.

Irrigation Systems and Terms

Before discussing irrigation works it would be useful to describe and define shortly the various methods in use.

(i) *Balagh.* The native word for land flooded by natural overflow from the Gash. The term is now used for all watering not by irrigation channels, and includes side-spills from one-bank canals, land watered by breaks, and also true 'balagh'. Watering is uncontrolled in 'balagh' areas and the growth of weeds and scrub so heavy that clearance costs rule out cultivation in most cases.

(ii) *Shaiōt.* The old native system of irrigation from a cut tapping the 'balagh' or a small khor and leading the water on to cleaner land. The term is used both for the canal itself and for the area irrigated by it. The use of 'shaiōt' has now been almost entirely discontinued, except south of Kassala.

(iii) *Cuts.* This term is used for channels irrigating by end-spill only, with or without a regulator at their head. Some of the existing canals were developed from these. A cut may take off a 'misqa', in order to spread the water-flow, and may also be used for irrigating a well-centre.

(iv) *Canals.* The function of the canals is to draw off from the river (or its branches) a controlled supply of water and to carry it to where it can be released to spread on land which is reasonably clean and free from heavy bush or grass. There are five main artificial canal systems from north to south—Mekali, Magauda, Tendelai, Mitateib, and Hadaliya: in capacity they range from 4 m.^{3} per sec. to 20 m.^{3} per sec. They are provided with regulators at their heads to control the admission of water and with cross-regulators at suitable points to facilitate distribution. In addition, at the north end of the delta, Khor Awadai (a natural channel of the Gash) has been canalized to water the Illibilli and Bahabini areas. In the upper part of the delta other smaller channels, such as Halenga, Ankora, and Tugarar, supplement the areas irrigated by the main canals. The head-regulators consist of a varying number of sluices 2·5 metres wide, usually 2 or 3 in number, with 5 in one and 4 in two cases. Flow is controlled by the insertion or withdrawal of steel girders forming horizontal stop-joists.

(v) *Misqa.* These are field watering-channels, spaced at suitable points on the canals, which carry the water directly on to the land. Originally the heads were controlled by screw-operated doors fixed to pipes, but later heads are usually of brickwork with 1–2-metre openings. From their heads the 'misqa' lead northwards down the general slope of the country and discharge water on to the land; usually the 'misqa' is laid out to cut across contour lines and discharge at the tail, but side cuts are also used. Various bed-slopes have been tried, but a steeper slope than that of the canal is now usually employed, so as to carry away silt. The original canals usually had small 'misqa' watering in batteries, but later design favoured large 'misqa' capable of taking a large proportion, and sometimes the full discharge, of the canal and watering large areas. Modifications are continually being made in the siting and regrouping of existing 'misqa', so the number of these on any canal is no indication of the amount of land that can be irrigated. The area served by one 'misqa' may vary from under 500 to over 5,000 feddans.

(vi) *Intercanal Banks.* These are low earth-banks to prevent the water discharged from 'misqa' on to a chosen sector from spreading laterally into the adjacent (and resting) land. The name is also used for small-section

banks which deflect water to a particular area, or which close off khors or depressions which might otherwise draw off water from the flooded section, or which prevent the flooding of heavily grassed land. They form the only check to the natural flow of the water, once it has been discharged from the 'misqa'. The use of these banks was begun about 1925, and their employment has been steadily extended since that date.

Early Irrigation Works

A canal is said to have been dug near Kassala in 1841 which continued to operate for some 30 years before silting up. Native 'shaiōt' represent the earliest attempts to use the flood-waters for irrigation purposes. The efficiency of 'shaiōt' varied: the feeder canal was often winding and of varying cross-section and bed-level, and so required heavy annual maintenance. It was difficult to control the discharge of water from the canal and so the irrigated area usually became very overgrown with weeds after a few years' flooding, despite any attempts made to introduce a rotation of crops. One or two of the smaller canals, e.g. Anber (now disused), have been developed from the old 'shaiōt' system. In 1905–6 a stone weir was thrown across the Gash 2 miles upstream of Kassala. A canal was dug at the same time to irrigate the Feddadin area, a large block of rather inferior land lying between Kassala town and the hills to the east of it. A system of basins was also constructed at Debelaweit, some miles north of Kassala, about this time.

In 1910–11 a larger project was undertaken in the construction of the Gulusit basin. This was formed by a strong retaining bank, astride the Western Gash, which was provided with a brick regulator to discharge surplus water to the Western Gash. This scheme operated fairly successfully for several years, but the levels inside the basin were raised by heavy silt deposits, gradually throttling the Western Gash and eventually diverting the entire flow of the river down the eastern branch.

During the years 1912–23 small cuts and canals, sometimes provided with a head-regulator, were constructed at Wad Sherifai, Ankora, and elsewhere.

Later Irrigation Works

The Kassala Cotton Co. took over the agricultural management of the delta in the 1924–5 season. In preparation for this transfer two fairly large cuts were made prior to the 1923 flood, at Hadaliya and Mekali, and tenancies were allocated and run on the lines to be adopted the following season. These cuts were subsequently provided with head-regulators and, with modifications and extensions, were incorporated into the present canal system. The Kassala Cotton Co. also started the construction of the Magauda canal in 1923 and completed 17·7 km. (with 23 'misqa') before the 1924 flood. This canal has since been considerably extended and modified in its design.

Further large additions were made as follows: Ankora (or Rabakassa): extensively remodelled in 1926, abandoned after 1929, but remodelled and reopened in 1940. Anber canal: developed 1925–6, abandoned after 1927.

Mekali: largely remodelled over the period 1926–9. Tendelai: originally constructed by the Kassala Cotton Co. in 1926 and operated and extended by the Gash Board from 1927 (their first season). Metateib: originally constructed by the Kassala Cotton Co. in 1924–5 and extended till 1932. Hadaliya: developed from cut made in 1923. Illibilli: constructed in stages between 1930 and 1936. Bahibini: constructed in 1930–1 in two stages.

Since their original construction most canals have been modified in many ways. Bed-slopes have been redesigned, 'misqa' have been cut out or regrouped, and extensions or new branches have been constructed. Silting of the head-reaches of canals has proved one of the major problems and, in several cases, regulators have had to be abandoned and replaced by others farther upstream, connected to the old canal system by a switch channel.

From 1926 onwards the state of the river-bed at Kassala gave anxiety and, in addition to the normal protection works to prevent the flooding of Kassala town, a system of river-training banks was planned. The 1929 flood was exceptionally large and did much damage; in consequence a large programme of river-training works was undertaken between 1931 and 1935. These works consisted of a series of opposing spurs with armoured heads, silted at ½-km. intervals over the 3-km. stretch downstream of Kassala weir. The centre section of the old masonry weir was cut out and the remaining portions incorporated in the river-training system.

The object of the training works was to prevent dispersal of the Gash flood at the apex of the delta, confining it to the Eastern Gash Khor. This apex, being at Kassala, meant that the training works served also as town protection works.

Downstream of the training spurs a system of earthen protection banks was constructed and strengthening by stone pitching has been carried out where required.

In 1939 the following irrigation works (in round figures) were in service: 220 km. of canals; 300 km. of 'misqa'; 85 km. of banks; 500 km. of intercanal banks and well-centre banks; 37 major structures including 3 railway bridges; over 100 minor structures.

Irrigation Methods

The Gash Delta provides an excellent example of controlled flush irrigation from an erratic and seasonal alluvial torrent. It is irrigation in its simplest—and also roughest—form, consisting essentially in leading water to a point whence it may debouch on to a suitably prepared area and cover evenly as much as possible thereof.

The use of flush irrigation, with its characteristic of one heavy watering only, given before sowing, is made possible by the water-retaining properties of Gash soil. Compared with Gezira 'badōb', Kassala alluvium contains up to twice the amount of silt (content up to 40 per cent.), shows a better permeability and capillary rise, and a much better penetration—from 13 to 18 ft. as against 5 ft. for the Gezira soil. Only the top 2 ft. appear to be affected by evaporation, with a resultant loss of about one-sixth of that which occurs in the Gezira cotton season.

All irrigation is from the main or eastern Gash khor, and the major engineering problem is to maintain the *status quo* of this channel as long as possible against the natural tendency of a deltaic river to swing from side to side as silt is deposited and land levels built up. Maintenance of the eastern khor is therefore in essence the resistance of a natural trend.

Canal off-takes require to be sited with care. It has been found that the best results follow an off-take leading diagonally away from the outside of a stable bend. Off-takes must be suitably silt-selective. Silt is present and must be dropped somewhere. If it is not carried through to the land, it drops in and chokes the canals and the khor. Therefore each off-take should take, and each canal carry, silt in proportion to the fraction of river discharge used. When a site is selected, suitable regulator size depends on water-levels to be expected in the Gash and required in the canal. The river-level used is the probable level which will be held for the length of time necessary to irrigate the land depending on the canal.

In the Gash Delta, canal sections tend to steep sides in solid silt, with flat sandy bottoms. Originally they were designed to run at 1/3,000 slope, but this was found too low in general and slopes were increased gradually to as much as 1/1,500: the average is now 1/2,500 or steeper. Surface velocity, in full flow, varies from 1·7 to 2 m. per sec. compared with 2·5 to 3 m. per sec. for the Gash—where the maximum recorded is 3·7 m. per sec. Silt is deposited evenly on the flat bed, making for ease of computation and setting out for annual clearance. The average deposit in canals during a flood is from 20 to 40 cm.; depths of 70 cm. are not uncommon, and 1½ metres have occurred over short reaches. Owing to the high silt-content, it is advisable to avoid checking the flow by intermediate regulators, unless such are obligatory to secure sufficient level to supply an off-take.

'Misqa' off-takes must, like canal heads, take their proportion of silt. As there is no choice of position, various silt selective devices such as vanes or divide walls in the canal bed, or sills in front of the heads, have been tried, the former to ensure proportional distribution of silt, and the latter to exclude excess bed-silt in cases where canal bed has risen above the 'misqa' off-take. Experience has shown that open sluice off-takes are better than pipe regulators.

'Misqa' are short canals running at very steep water slopes, merging as they do into sheet-flow over the ground. Uninterrupted flow is essential, and therefore side-cuts are to be avoided. Silt is deposited heavily at the end of the 'misqa', where velocity drops suddenly as the water begins to spread over the land. Therefore, they have to be extended each time they are operated, and eventually become too long to run swiftly enough to carry forward their silt. In such cases they are either swung to a new line at an angle, or are completely resited.

While control at the canal head is based on the expected Gash level, control at the 'misqa' tail is based on the land level. Design must allow for even slopes from head to land. In practice, therefore, the minimum canal level to give a full supply is established for each 'misqa' off-take and at or above these water-level and slope selected for the canal. Each season different canals come into action, and each presents a different problem in design and distribution. There can, therefore, be no stability, although a cycle of

alternative designs may emerge suited to the 3-year crop rotation now in force.

A prerequisite to all design is a knowledge of the water duty required. Observations by the Kassala Cotton Co. established a figure of from 5,000 to 8,000 cubic metres of water for each feddan of effective cotton area. Taking a mean of 6,000 cubic metres, the use for irrigation of *all* the 400 million cubic metres of the average flood should suffice for 67,000 feddans. The use of all the water being impossible, an average flood may be assumed to suffice for about 50,000 feddans of cotton. Present practice is to allow a rate of supply of at least 1 $m.^3$ per second for every 500 feddans of potential area, the total quantity depending on the time during which this is applied.

The watering period to produce the most effective results for the varying soil-types has been the subject of controversy for many years. Numerous experiments have been made and, generally speaking, the tendency has been towards a reduction of periods (originally a period of 30 days was assumed). It is now thought that the optimum watering for 'lebbād' soils is from 10 to 12 days, and for 'badōb' from 25 to 30 days. It will be readily realized that, with the system of watering adopted, a balance must be struck in every case: land near the 'misqa' discharge is over-watered, whilst the fringes of each irrigated block are capable only of producing a short-term dura crop. The watering of areas of mixed soils is based on the relative percentages of 'lebbād' and 'badōb' included in the block involved.

On each canal, areas to be irrigated are divided into two blocks, the first and second rotations. As soon as suitable irrigation conditions are obtained the flooding of the first-rotation 'misqa' canals commences, and continues for the necessary period. These canals are then closed down and the water is released on to the second-rotation areas, which may receive a flooding fully as effective as that of the first rotation; erratic Gash levels, or a tailing off of the flood, may, however, result in incomplete watering. The sowing and cultivation of the second-rotation areas is thus begun fully 15 to 30 days later than that of the first rotation; this delay helps to spread the labour supply available. Where the flood is poor, or otherwise threatens the adequate watering of the second-rotation areas, prompt decision may be required on the merits of closing down on first rotation rather earlier than desirable, in order to get better results on the second.

The actual opening of canals for flood depends on the state of the river. The early, heavily silt-laden, dirty water is not desirable. Great harm may be done by opening too soon, on an early flush which dies away; slackening, and especially interruption, of flow in a 'misqa' causes the water to recede on the land, promotes grass growth, and is never fully recovered. For this reason, too, use may not be made of the peaks of the sudden sharp spates so characteristic of the Gash—quite apart from the totally disproportionate enlargement which would be necessary for channels and structures. Opening is then deferred until satisfactory river conditions have endured for a few days, and promise to continue. As a general rule, opening for the first rotation should not occur before about 15 July, and should not be postponed later than 25 July.

Before each flood, design levels corresponding to full supply, and maximum levels, the highest which may be run in safety, are laid down for each canal. Regulation is made at the head-regulator to maintain design canal-level; the actual water depth is measured and, as the canal slowly silts, so is the design-level raised—to the maximum, above which continued silting means diminuation of supply. Along the canal, where several 'misqa' canals are in use, rough regulation at 'misqa' off-takes is employed if necessary, to ensure that all run as well as possible; this usually consists of slight reduction of the upstream off-takes to pass more discharge to the lower. The ruling levels, order of opening canals and 'misqa', and useful operational data are laid down by the engineering staff in 'Watering Instructions' issued by the manager before each flood. The actual control during flood passes to the Agricultural Staff, except in cases of emergency.

During the flooding of each 'misqa' careful maps are made at regular intervals of the spread of water, and a final map prepared at the end of watering, on which allotment is made. Study of these maps over a series of years yields valuable data for future betterment of flooding of each area.

Gauges are recorded thrice daily during flood of the Gash and the canal at each off-take. Discharges, by the surface float method, are taken regularly of the Gash at Magauda, and as frequently as possible at other sites along the khor and in the head reaches of canals. The latter are not very informative, due to the steady silting of nearly all head reaches annually.

Surplus water is released through three escapes at the northern canal head and also, during high spate, by natural overflow on the east bank.

Administration and Financing of the Crop

In earlier days the Province Staff supervised all cultivation, but from 1918 to 1924 the Department of Agriculture controlled the irrigation and general cropping of the Gash area. When the Kassala Cotton Co. assumed the management of the delta all claims to land ownership were abrogated, and the whole area transferred to the company as a concession. After three seasons' working the company surrendered their rights in the Gash Delta and were granted a block of land in the Gezira instead. The agricultural administration of the delta lands then reverted to the Sudan Government, and a board, known as the Gash Board, was formed. Its present constitution is as follows:

Chairman and Managing Director:	Director of Agriculture and Forests.
Directors:	Governor, Kassala Province.
	Director of Irrigation.
	Finance Department representative.

The Manager of the Gash Board, together with the Secretary, are both found by the Agricultural Department, and meetings are held from time to time to discuss and settle questions of policy, finance, projects, &c.

The local management falls naturally into three main branches: agricultural, irrigation, and accountancy. British staff is seconded to each

section as required, and the manager is in general control of the various activities. The profits from the Gash cotton crop are allocated as follows:

Tenants	50 per cent.
Gash Board . . .	30 ,,
Government . . .	20 ,,

With large crops the Government share increases somewhat at the expense of the Gash Board percentage.

For supervision the delta is divided into six stations: Kassala, Mekali, Degein, Tendelai, Mitateib, and Hadaliya. The headquarters of the Board and the central workshops are situated at Aroma.

In general it may be said that expenses are shared between the various parties, but the tenant is charged with the cost of cotton seed and is responsible for the cultivation expenses of this crop. Advances are made, as and when required, to tenants to finance these operations, and are debited to the tenant's account. All tenants are encouraged to grow a dura crop, free of any charges, equal to one-fifth of their cotton area.

Land Allotment

The unit of division is the 'qit'a' of 10 feddans, but this may be subdivided into 5-feddan tenancies, which are the commonest individual holdings. Capable cultivators may have larger holdings, and tenancies of 50 feddans are quite common Allocation naturally varies from year to year, according to the vagaries of the flood, but the areas sown with cotton over the three pre-war seasons were:

	Actual areas (feddans)				*Potential figures*	
	1936–7	*1937–8*	*1938–9*	*Average*	*Feddans*	*Tenancies*
Kassala	945	1,300	1,700	1,315	2,500+	700
Mekali	1,400	2,121	3,257	2,259	4,000	800
Degein	6,946	6,022	5,999	6,322	6,000+	1,200
Tendelai	4,968	7,267	8,186	6,807	9,000+	1,500
Mitateib	9,203	8,928	8,831	8,987	9,500	1,500
Hadaliya	12,088	8,794	8,545	9,809	10,000+	1,500
Totals	35,550	34,432	36,518	35,499	41,000+	7,200
Tenancies	6,790	6,655	6,245	6,563	..	..

The last columns show the areas and tenancies likely to materialize if ideal irrigation conditions were obtained at all stations. In 1931–2 the tenancies amounted to 3,300 only, so individual allocations have roughly doubled for a 50 per cent. increase in the cotton area cultivated, i.e. the individual holdings have tended to become smaller.

The land is Government-owned and is allotted rent free for the period of one crop. Allotment is made on a tribal basis, and sheikhs and subsheikhs are given a block from which to satisfy the requirements of their followers.

Owing to the rotation adopted (cotton—resting—resting) the situation of the individual's holding varies, but satisfactory cultivators are assured continuity of tenure.

The indigenous tribes hold by far the greatest portion of the land. The percentage allocation within recent years has been:

	1933	*1934*	*1935*	*1936*	*1937*	*1938*	*Average*
Indigenous .	71·7	70·7	71·1	73·2	72·0	73·0	71·9
Riverain .	4·5	5·3	3·9	4·1	5·8	5·0	4·8
West African .	23·8	24·0	25·0	22·7	22·2	22·0	23·3

The indigenous tribes comprise the Halenga, Bani Amer, Amarar Mirghania, and Hadendowa, the last named being most strongly represented.

The riverain group includes seekers of fortune from the Nile valley, mainly consisting of Gaalin and Shaigia from the northern Sudan.

The last category comprises West Africans—Haussa, Fellata, Burnu, Burgu—and the black tribes from the southern Sudan.

The riverain cultivators are probably the most satisfactory tenants, as they are hard-working, intelligent, and adaptable. The West African are also industrious and seldom resort to hired labour.

The indigenous tribes were, within recent times, mainly pastoral, but many of the tenants have now adapted themselves successfully to a new and more settled mode of life.

Agricultural Operations

The new season may be said to commence in May, when the preliminary land allotment is carried out. This is done on a tribal basis, according to the size of the tribe and its known ability to cultivate; the areas allotted are based on the expectation of a fair flood and a good spread of water.

After allotment the tribe is responsible for preparing the land for water. This necessitates clearing all bush, repairing control banks, and clearing out the 'misqa' that waters their holding. The latter operation is sometimes done by contractors, under the supervision of the Engineering Section, but the cost is borne by the cultivators. After the land has been cleared it is demarcated in 10-feddan units, which may be further subdivided by the tribal Agricultural Sheikh for more detailed allotment.

On the completion of watering the first allotment is revised (usually curtailed) to ensure that the well-watered land is equitably distributed. Land which has been only lightly watered is sown with dura.

Cotton seed is now issued and the land is sown as soon as the cultivators can move about; the 'selūka', or pointed stick, is used for both cotton and dura planting. The optimum spacing for Gash cotton is 1 metre by 1·10 metres, and stands are thinned to four plants per hole. The native cultivator likes to sow thickly and takes badly to thinning, but this is essential, and it is carried out after the third or last hoeing. Owing to the fertility of the Gash soil weed growth is rapid and heavy, and, unless hoeing is carried out at once, the crop may well be smothered. On the average three weedings are necessary, and the African hoe is the usual tool employed.

Cultivators may have an area of rain-grown dura in addition to their

irrigated allotment; this they are able to harvest between the establishment of the cotton crop and the commencement of picking in January. The irrigated dura crop is harvested in December and January.

Cotton picking is in full swing by January and continues until the end of May, when all plants are pulled out by the roots and burned as early as possible in order to ensure the maximum dead period before the sowing of another crop.

With the commencement of picking, cotton markets are opened at selected railway stations. Here the cotton is taken over from the cultivator in sacks and weighed. The sacks are issued through sub-stores, against payment by the cultivators, and the transport of the picked cotton from the fields to the market is the cultivator's responsibility. The further stages, from the station market to the ginning factory, and thence to the buyers is a Government liability.

Cotton is inspected in the field for general cleanliness before being sent to the market, but the final grading and classification is done at the ginning factory.

Cultivators are paid a *pro forma* price for their cotton on the market weight, and when the crop is ultimately sold a final adjustment payment is made.

Cotton seed for the next crop is sent to the Gash from selected sources and is sunned during the hot weather; it is then stored at the various stations for issue to the cultivator, against his account, at the start of a new season.

Wells and Water-supply

One of the main problems has been the provision of adequate water-supplies to the scattered cultivating population. Wells exist in many centres, but they vary both in the amount of water they provide and in their persistence. Some wells function throughout the year, whilst others dry up by April or May. A list of 119 known well-centres has been drawn up, of which 16 established well-groups provide the bulk of water required by the native cultivators and their livestock. The principal centres are surrounded by banks, and the water-table is replenished annually by flooding through channels from the canals. In many places two water-bearing strata exist, a higher and a lower, and advantage is taken of both levels.

In addition to those supplies there is a pipe-line, extending from Gammam to Hadaliya, with various branches and with one or more water-tanks situated on each canal. The main pumping-plant is sited at Gammam, but auxiliary sets exist at Mekali: the plant at the latter place was originally used for a lesser distribution in Kassala Cotton Co. days, but is now retained to augment the supply. The pipe-line extends for a total length of some 95 km. and is designed to supply 100,000 gallons daily. This has proved adequate for all requirements to date, though the draw-off has to be controlled towards the end of the dry season (April–June). The Gammam water-table levels have given anxiety of late, as these were falling. The supply has been improved by the cleaning of Khor Salaam Aleikum and by sinking open wells near the Gash bed. It may, however,

prove necessary to extend the pipe-line southwards in future in order to obtain an assured supply from other sites.

General

(i) *Demarcation.* The original contour survey was begun in 1920 and the demarcated area has been extended subsequently. The whole delta is demarcated by Survey beacons running roughly (but not exactly) north and south and east and west. The largest subdivision is the 'hōd' (basin), a 4,000-feddan area. Each 'hōd' is subdivided into 25 'murabba'' (square) of 160 feddans, which are again divided into 16 'qit'a' (portion) of 10 feddans. The 'hōd' are numbered, and in each 'hōd' the 'murabba'' and 'qit'a' are similarly numbered—from 1 to 25 and from 1 to 16 respectively. The corner of each 'murabba'' is marked by an iron beacon with number plate. Thus each unit of 10 feddans can be precisely located by reference numbers—e.g. 'qit'a' 195–15–8 means No. 8 'qit'a' of No. 15 'murabbā'' of No. 195 'hōd'. Subdivision of the land in the squares due for irrigation is made each season by chainmen. For practical purposes each side of a 'hōd' measures 4,100 m., of a 'murabba'' 820 m., and of a 'qit'a' 205 m.

The total area demarcated in the delta now amounts to some 720,000 feddans in all. A further 25,000 feddans (undemarcated) exist in the Kwenti–Kalahote area, so the potential cultivable area is some 750,000 feddans. Only part of this area is suitable for cultivation, and from it the gross total capable of development by irrigation would probably not exceed 400,000 feddans. Even this figure could not be exploited with the watering periods at present adopted and the labour supply available.

(ii) *Climate.* The rainy season extends over the period May–September, and the bulk of the rainfall coincides with the flood period (July–September). The annual average rainfall for Kassala town is 327 millimetres (13 in.), but this figure decreases by at least one-third as one proceeds northwards through the delta.

The incidence of rain-storms during the period of Gash flooding has, therefore, to be taken into consideration, and the flow of the river itself is often heavily augmented for short periods by rain-water brought in by tributary khors from the east. Rains may also increase the growth of grass and weeds and delay the cleaning of flooded land.

The persistent winds that are found at Tokar do not occur in the Gash area, though dust-storms ('habūb') and dust-devils are often met during the months of May and June. Temperatures are also high during these months. Heavy dews often occur from December to March which greatly benefit the crops.

(iii) *Pests and Diseases.* (*a*) *Cotton.* Leaf curl was first noted in 1928–9 and has often caused much loss, especially in the Sakel types. Blackarm is never very severe. Bollworms, of all types, are usually found each year on the cotton crop; the major damage is usually due to pink bollworm (*Platyedra gossypiella* Saunders). Thrips and cotton aphis are usually found to a greater or lesser extent and sometimes cause severe seasonal losses. Crickets and grasshoppers often attack seedling cotton and are thereby responsible for much of the resowing done.

(*b*) *Dura.* The dura crop often suffers damage from birds: the two main

FIG. 291. Gash delta: Hadendowa cattle watering at Gulusit wells (*photo G. J. Fleming*).

FIG. 292. Gash delta: scaring birds from dura by cracking a whip (*photo G. J. Fleming*).

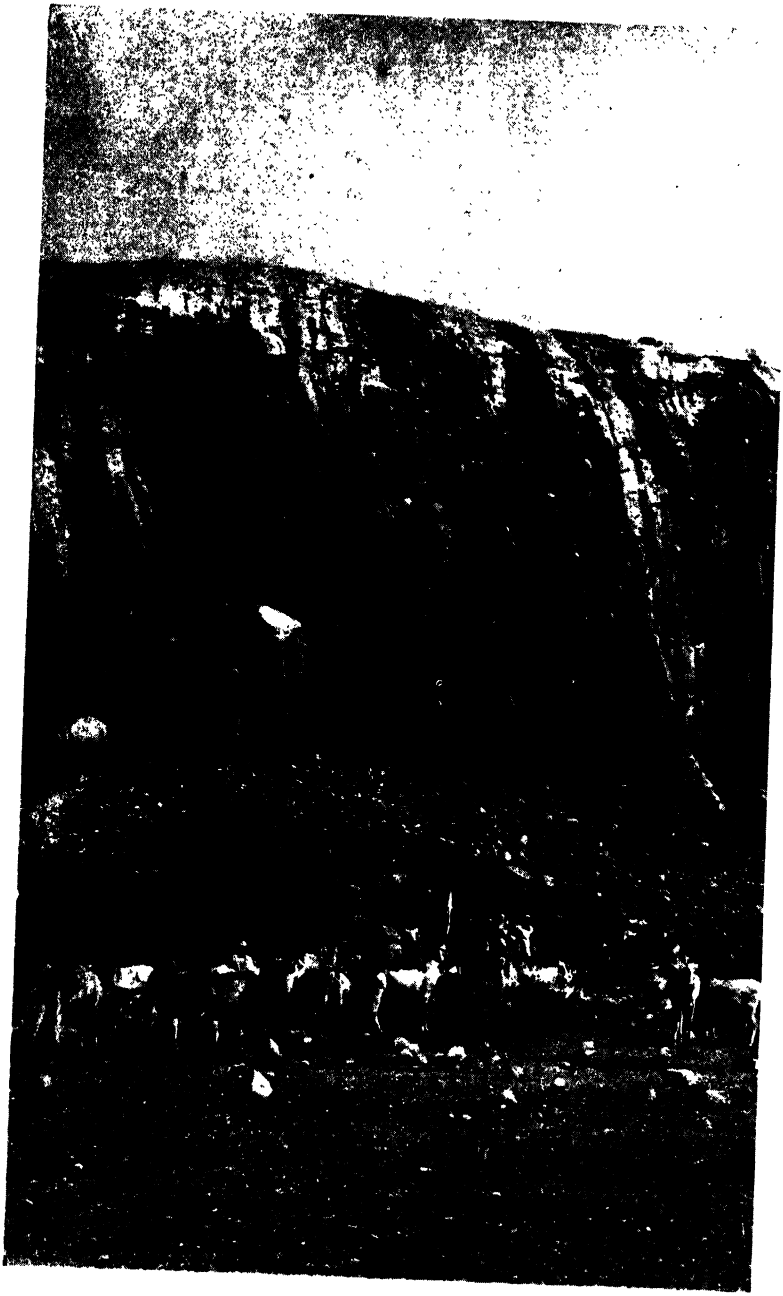


FIG. 293. Beita Rock, between Gedāref and Mafāza. Cattle watering at the deep wells there (*photo E. Mackinnon*).

culprits are the Spanish sparrow (*Passer hispaniolensis* Temm.) and the weaver-bird (*Quelea quelea aethiopica* (Sund.)). The insect pests which do most damage are the stemborer, and the periodic invasions of locusts. The various forms of dura smut are also prevalent.

(iv) *Gash Duras*. The local duras, as noted previously, have for a long time been famed for their general excellence. In general they are large-grained, compact-headed duras of very good quality. The 'gassab' is tall and the maturation period is slow as a general rule.

Yields may amount to 10 ardebs or more of grain per feddan (3,360 rotls) in well-flooded alluvial land, but the average yield is probably about one-third of this figure. The well-known local types include Gertai or Egratai (orange and yellowish-white grained varieties); Aklamoi (two types of similar coloration); Shebbat (buff and reddish types); and Tawleeb (light buff). The last named takes 140 days to mature, and there has been a tendency of late to grow rather quicker-maturing duras such as Zinnari, introduced from Kordofan.

(v) *Weeds*. It was originally hoped that a two-course rotation (cotton—rest) could be adopted for the Gash. The growth of grasses and other weeds proved so heavy that an extra rest had to be introduced. The main weeds found are grasses and sedges: 'nagīl' (*Cynodon dactylon* Pers.); mordeib (*Paspalidium desertorum* Stapf.); 'umm asābi' (*Dactyloctenium aegyptium* Beauv.); 'adar' (*Sorghum* spp.); 'sēd' (*Cyperus* spp., chiefly *C. rotundus* Linn.). Other: 'ushar' (*Calotropis procera* Ait.); 'dahassir' (*Indigofera* spp.); 'seseban' (*Sesbania sesban* (L.) Merr. Of these the sedges (*Cyperus*) are the worst, owing to their persistence, and deep cultivation by tractor has been tried in the most heavily affected areas.

(vi) *Quality of Gash Cotton*. The quality of cotton produced in the delta is very high, and the various grades produced command a premium over similar cottons grown in the Gezira and elsewhere in the Sudan. The Gash has accordingly been used as a seed-producing centre, and the bulk of the Gezira's seed requirements has been obtained from this source for many years.

Southern Kassala Province

General

The agricultural significance of the southern district of Kassala Province, which now incorporates the former Gedaref district (with its one-time sub-districts of Mafaza and Gallabat) and the former Butana district (with its sub-district of Abu Deleig), is due to, and measured by, its rainfall.

Of the whole Sudan, this district is the only one in which a railway runs through country with average rainfall of over 600 mm. Its relative proximity to the port, when compared with the other areas of the Sudan on the same, or on a wetter isohyet, enhances the site value of its exportable production.

The district has been formed by the fusion of the predominantly pastoral Butana district with the predominantly agricultural Gedaref district, and it is with the latter that this chapter is principally concerned.

The vegetational features have been broadly discussed elsewhere, but

in general it may be said that the most northerly division between the pastoral and rain-cultivated areas starts with the *Acacia mellifera* Benth. ('kitr') belt. This zone, on its wetter side, allows for a reasonably assured dura production; the drier side permits of the growing of quick maturing Feterita dura in most years.

To the south-east of the 'kitr' belt the *A. senegal* (L.) Willd. 'hasbāb' region is entered and this species is advancing northwards into the 'kitr' region between Gedaref and Esh Showak. The 'hashāb' region occupies the heavy cracking clay soils, and the slower maturing duras and sesame are capable of successful cultivation in this belt.

In the chocolate clay soils of the Gedaref region *A. drepanolobium* Harms. ('sofar iswid') and *A. campylacantha* Hochst. ex A. Rich. ('kakamūt') are typical, merging into the vast *A. seyal* Del. ('talh') belt to the south. This region has an assured rainfall, allowing for the cultivation of a wide range of duras, of sesame, and of leguminous crops. To the extreme south-east of the province the *A. sieberiana* DC. ('kūk') series is encountered in the Gallabat area. Here the soils and rainfalls would permit of the growing of most crops, including cotton.

Soil Features

The southern district is a vast plain of clay soils: there appears to be an increase in clay content south-eastwards, coinciding, that is to say, with the increase in rainfall. The average ground-slope is approximately 2·5 metres per km. Isolated hills and rocky outcrops pierce the plain at wide intervals. These form almost the only sources of the seasonally running khors, none of which are known to have their origin on unbroken clay plain.

Restricted islands of red soil occur in some areas; such are seen at Azaza, north of Gedaref, and elsewhere.

Limited areas of chocolate-coloured cracking clays, apparently formed *in situ* from basalt, give character to several areas, e.g. around Gedaref and at Hillat el Omda, north of Doka. Grass plains, breaking the continuity of the Acacia forests, are locally known as 'sagea'.

Wide areas of clay are often found, remote from hills, with small quartz stones scattered across the surface. Such areas are esteemed for cultivation and the soil is known as 'bashendi'.

The river Atbara has cut for itself a deep valley into this clay plain. The resulting drainage slopes between the plain level and that of the river-bed, subjected to erosion by even limited amounts of rain drainage-water, have been carved into a fantastic régime of gullies and gorges. At the lower levels of the 'kerrib' (as this region is called) are exposed deep faces of soil 'cliff' revealing the alluvial origin of much of the material, at former higher levels of the valley. The 'kerrib' slopes are of raw unfertile soil with pronounced surface 'gravel' (of calcium origin) left by erosion of the finer particles. It is anticipated that *Prosopis juliflora* DC. (mesquite), a failure on basalt clays, will provide a means of ultimate utilization of many of these 'kerrib' soils, and the first experiments have (1943) been begun at Esh Showak.

Riverain Soils. By comparison with the great extent of good rainland

the narrow and purely riparian fringes of recent alluvium along the river Atbara are insignificant in the agricultural economy of the district.

There are much wider areas of very rich riverain soils around the present meanderings (and the ox-bow lakes which mark former channels) of the river Rahad. Within recent years irrigation has been started on the Rahad; two small pumps, drawing water from the permanent pools, have proved a success, and an increased use of irrigation is probable. These make a significant contribution in green vegetables to populations along the railway to the north and south of Hawata. Citrus fruits, pawpaw, bananas, mangoes, and mulberries can be developed on these soils to raise the dietetic standards of the whole district and of areas farther afield. Wide areas are capable of growing, and have grown, Sakellarides cotton, sown on rainfall and matured by soil-water of rain and river seepage

General. The rainland clay plains exhibit deep cracking in the winter and assume a crumb condition throughout the dry season. Where unpuddled by traffic they form a good tilth under rainfall, are much less 'sticky' than Gezira clays and rarely, if ever, show standing water even after the heaviest rainfall, save where a hill plinth or other such catchment has induced run-off to a neighbouring area. It is a characteristic of these clay plains that they are capable of absorbing the bulk of the heaviest rainfall they ever receive, losing little by run-off. For their wet condition 'spongy' is a better description than 'sticky'.

Population and Water-supply

The vast and now unpeopled Acacia tall grass forests as well as the open grass plains or 'sagea' of Gedaref, Mafaza, and Gallabat, are strewn with evidence of former population. The Atbara valley also shows many deserted village sites—old hill-foot water pools, rock carvings—and 'hafirāt' hill-top non-Moslem cemeteries, while they do not provide the means reliably to gauge the strength of a former population, at least prove a distribution vastly more extensive throughout the district than exists to-day. Many elders testify to the former existence of a heavy population up to the time of the Mahdia in the middle eighties of the last century. The decimation is thought to have been caused by a combination of smallpox and cerebrospinal meningitis following years of cattle plague and famine and to the resulting capture of grass plains by Acacia forest.

These water-storage relics are now silted up, and in the main useless. In some cases it is doubtful whether the drainage régimes on which they are sited are now capable of filling them, even if re-excavated.

The very number of these storage relics points to well-water having been as difficult to reach in the past as it is to-day, in these clay plains which are impervious to the downward movement of rain-water for more than a few feet.

The film, thick or thin, of population which once covered these plains contracted, leaving shreds of itself adhering to sites of easy water, usually hill sites. The deliberate settlement of westerners after the reoccupation did little more than enlarge these shreds. Strong, recent, and spontaneous settlement by Fellata types along the crest of the 'kerrib' of the river Atbara

upstream of Sofi (some 10 miles south of Esh Showak) and a steady growth in population at Hawata and along the Rahad, despite its bad medical reputation for being unhealthy, have been more significant changes than anything else which has happened to the area since the eighties. There has also been a big increase, within recent years, of the Fellāta and western Sudan tribes in the region extending from Doka to the neighbourhood of Gedāref. But the whole area, considering its assets of soil and rainfall, is carrying only a small fraction of the population the area could support.

The vast potential developments of which these plains are capable are locked inside a door to which there are two keys.

The first is drinking-water; the second is control of disease, in particular malaria and kala-azar. By reason of disease the river Rahad, in its present condition, cannot be regarded as a suitable centre for settlement.

Development of the hinterland requires more water than can be provided by 'hafirāt' and wells. In 30 years of steady work a substantial proportion of the suitable catchments have been trained and fill 'hafirāt'. On a scale limited to the utilization of local talent, wells have been increased and improved. But these two methods have failed to provide for settlement ot the best areas on an adequate scale, and it is held by most observers that only a piped water-system, starting on the upper Atbara and leading to the railway, will provide the conditions pre-required for real settlement.

Much of the preliminary work of survey for this Atbara scheme was carried out in 1936 and 1937, and only the outbreak of war in 1939 prevented the establishment of a small pipe-scheme based on the river Rahad upstream of Hawāta and intended as a pilot scheme to provide experience on which to base a decision on the major Atbara project.

Such an axis of development, running through the best soil and rainfalls, and remote from the unhealthy swamps and basins of the Rahad, offers prospects of rainland settlement on a scale not elsewhere to be equalled on the Sudan railway system.

Animals in Husbandry

The district, as has been noted, includes the line which divides the nomad steppe from the cultivation of the sedentaries.

That fact would lead us to expect to find mixed husbandry well developed, at least along that dividing line.

The various biting flies which follow the game migration northwards at the break of the rains make much of the agricultural part of the district unsuitable for cattle in the rains, and the sedentary cattle-owning cultivators are forced to drive part at least of their herds north with the nomads, although use is made of certain hills and open plains (known to be habitats not favoured by the flies) to keep milking-animals within reach during the rains.

In the dry season the abundance of wild grazing, when grass fires spare it, means that the dura stems are usually left uneaten by cattle, an embarrassment in subsequent cropping and a wasted asset save round the centres of population. There is no enclosure of arable land. The only common practice which resembles folding is seen when owners of dura

stubble on the nomad fringes on occasion make a bargain with a passing 'ferīq' of camels or of cattle, under which the animals are herded on the stubble until the best of it is eaten.

Studies in the identity and distribution of biting-flies, and in the protection value of clearances such as the grass plains (or 'sagea'), are needed before an improved cattle husbandry can be initiated.

Save for an occasional water-wheel on the Rahad, oxen are not used in transport or in cultivation, and development of their use is one of the greatest contributions which the future holds for the expansion of production in these rainlands. Like so many other developments here, it is linked to the water problem.

Crops and Cropping

Dura and sesame are the main crops; both are grown on a large scale, and the quality of both products is generally good. The dura varieties most widely grown are:

Mugud: commonest type, first choice for 'harīq' cultivation.

Wad Aker: very common, especially along Atbara because of its comparative freedom from bird damage.

Bargowi: a slow-maturing Fetarita type, common near Doka.

Hegeiri, Gassābi: high-quality duras, grown generally in areas of good rainfall.

There are no outstanding sesame varieties grown in the Gedaref area beyond the 'red' and 'white' types general throughout the Sudan.

There is normally a large export, both of dura and sesame, from the Gedāref district to other parts of the Sudan. The area is capable of much greater production if the problems of labour and water-supply could be satisfactorily solved. The number of 'assāra' has trebled in Gedāref during the last few years, and the export of sesame oil, rather than the whole seed, has increased largely in consequence. Dukhn is not very widely grown, but it is popular with the Fellata; settlements of West Africans are found along the Atbara, Rahad, and around Doka, and these seem to be increasing steadily.

Maize is generally found on riverain soils only. High hopes for cotton were built on the undoubted success of American cotton in 1923–6. Thereafter no really satisfactory results were ever obtained, partly on account of the occurence and rapid spread of thrips, and partly because of the apathy of cultivators after prices for cotton had slumped. Cotton has been grown for generations in the group of villages near Gallabat and also around Doka, and most of this for at least forty years has been sold into Abyssinia. A small quantity is still grown on the Rahad riverain soils, where American and even Sakellarides cotton can persist as perennial plants. 'Lubia hilu' (*Vigna unguiculata* (L.) Walp.), tomatoes, okra or 'bamia' (*Hibiscus esculentus* Linn.), some water-melons, including 'battīkh' (*Citrullus vulgaris* Schrad.), 'ads sudani' (*Cajanus cajan* (L.) Mill) sweet potato (*Ipomoea batatas* Lam.), and ground nuts (*Arachis hypogaea* Linn.) are also grown on a small scale. Among attempted introductions cassava is a proven failure.

Cropping methods are dealt with elsewhere in this book and it will suffice to record local practice in brief.

The cultivated rainlands are divisible into two categories, those lands around or at least near villages on which land cultivation is perennial, or at least is practised for long periods without rest to the land. Such areas are known as 'bilad' lands.

The second category includes cultivation, usually dura, sited more distant from villages, either to avoid damage by village animals or to take advantage of particularly good soil, particularly good rainfall, or particular freedom from weed growth.

'Harīq' and 'mahal' cultivation fall into this category. 'Harīq' is described elsewhere. The extensive 'sagea' and the enterprise of merchant cultivators make Gedāref the most famous 'harīq' district in the country. 'Mahal' is the name applied to land on which weed growth is poor, because of a seed failure consequent on poor rains of a previous year or after locust damage. 'Kommadōb' land is that form of 'mahal' which is due to 'harīq' burning in the previous season, and is followed by the condition known as 'dahr kommadōb'.

The plough is unused. Ridging is seldom if ever practised. The use of the 'terās' is rare except in the Butana areas.

Rotations, in the commonly accepted meaning of the term, are not practised. In 'bilad' continuous dura is grown when the land allows for the maintenance of satisfactory yields; dura has been grown for 40 years or more continuously in some areas. A rotation of dura–sesame–dura–sesame *ad infinitum* is also widely adopted; this seems less exhausting than continuous dura. Continuous sesame is never grown; and resting, except in the enforced resting of 'harīq' cultivation, is not used except where soil exhaustion occurs. The introduction of a leguminous crop into the shift would probably be of great benefit, but there is no legume sufficiently popular locally to merit growth on a large scale.

Dura is sown by 'selūka'; sesame is broadcast.

The labour needs of harvest constitute a bottle-neck tending, especially in the case of sesame in peace-time, to limit the area sown per family. The ripening sesame waits for no man, and a sharp breeze can ruin the crop not cut at the precisely appropriate stage. Mechanical threshing devices for dura would save almost as many man-days as the crop has needed for its production.

The whole field of experiment lies open in the application of drill sowing to sesame and dura, and of power hoeing of weeds.

When sesame values are steady there is a good prospect for co-operative or collectivized or company development of the southern areas of this district by machinery.

Fires and Grazing

The *Acacia mellifera* Benth. or 'kitr' belt can be described as *Acacia-short grass* country. The *Acacia senegal* Willd. or 'hashāb' belt, and all belts on the wet side thereof, form *Acacia-tall grass* country, and in this the annual grass fires are the predominant factor in the control of the vegetation, the whole of which is describable as a fire-climax vegetation.

The tall grasses are mainly annuals, having little grazing value. The short grasses, as on the basalt clays, are much better in this respect, especially types like 'dumbalab' and 'homra'. The green shoots of burned-over perennial grasses are much sought, but are of only local importance.

The *Acacia senegal* Willd. yields the highest quality of gum Arabic. Since most established villages of the southern part of the district are holders of tapping rights in gum gardens of *Acacia senegal* Willd., and since early grass fires ruin the yield of tapped trees for that season at least, there exists a strong incentive to fire protection. It is beyond doubt, in the opinion of competent observers, that a smaller proportion of the area is now burned annually than was formerly the case. But adequate fire-protection is still a far-distant target, and the problem is rendered no easier by the fact that protection is not always of direct value to nomads impinging on the area along its upwind boundary in the fire season. The protection of areas suitable for 'harīq' cultivation by fire lines is becoming increasingly practised (50,000 acres in 1943).

The Butana Region

North of the *Acacia mellifera* Benth. belt the rainfall is generally too light to grow satisfactory dura crops. Cultivation is therefore mainly confined to flooded wadis or to areas where 'terūs' can be constructed to conserve the rainfall. The chief wadis are in the neighbourhood of Abu-Deleig, where the country is generally less flat than in the expanses of the Butana lying south and east of this place. Cultivation by 'teras' or the low earth bank is mainly along the upper edge of the Atbara 'kerrib'.

The rainfall varies so much that effective cultivation cannot be ensured in any particular year. Nevertheless, the nomad Arabs have shown an increasing desire to cultivate such areas as happen to be favoured by rains.

APPENDIX: TOKAR DELTA

Cotton Production, 1925–40

Season	Approx. area in feddans			Total crop (kantars 100 rotls)[1]	Total value of cotton sold (£E.)	Average price per kantar (m/m)	Type of seed sown	Average yield (kantars) per feddan)	Remarks
	Flooded	Sown cotton	Effective cotton						
1925–6	31,000	22,000	14,400	31,745	53,727	1,692	Sakel	2·2	Seed *ex* Tokar.
1926–7	33,900	25,000	20,000	101,116	169,286	1,674	„	5·0	„ Gezira.
1927–8	60,000	50,000	45,000	168,381	439,082	2,607	„	3·7	„ Tokar.
1928–9	75,000	63,000	50,000	146,809	288,051	1,960	„	2·9	„ Tokar Seed Farm *ex* Gash.
1929–30	125,000	95,000	45,000	176,165	176,340[2]	1,024	„	3·9	„ Tokar, Gash, and Gezira.
1930–1	100,000	90,000	60,000	216,769	165,119[2]	767	„	3·6	„ Gash.
1931–2	85,000	65,000	38,000	168,231	112,673	669	„	4·4	„ Egypt.
1932–3	99,000	70,000	44,000	300,866	225,173[2]	754	„	6·8	„ Gash.
1933–4	70,000	55,000	37,700	71,253	64,232	903	„	1·9	„ „
1934–5	66,000	43,000	31,680	141,638	157,832	1,114	Sakel X1530	4·2 10·7	Gash Sakel 41,150 feddans. X1530 (*ex* Gezira) 1,850 feddans.
1935–6	25,000	21,800	14,050	107,191	125,026	1,166	X1530	7·6	Seed *ex* Gash and Gezira.
1936–7	82,000	65,000	43,000	375,564	435,004	1,157	X1530 X1530A	8·7	Seed *ex* Gash, Gezira, and Tokar.
1937–8	80,000	35,000	20,000	88,565	52,341	591	„	4·4	Seed *ex* Gash and Tokar. Much land lightly flooded.
1938–9	85,000	60,000	40,000	266,374	184,983[3]	710	X1730A Lecrem	6·7 5·0	X1730A. Seed *ex* Gash. Lecrem 1,150 feddans.
1939–40	54,000	35,000	27,000	202,173	212,350	1,046	X1730A NT/2	7·4 5·8	X1730A. Seed *ex* Gash. NT/2 cotton 160 feddans only.

[1] Consult glossary for meaning of unfamiliar terms.
[2] Excludes the value of Government seed-farm cotton.
[3] Value of 260,520 kantars X1730A cotton only. Lecrem cotton marketed separately.

APPENDIX: THE GASH DELTA

Cotton Production, 1924–40

Season	Approx. area in feddans: Sown cotton	Approx. area in feddans: Effective cotton	Total crop (kantars of 315 rotls)	Average yield (kantars per feddan)	Authority supervising cultivation	Remarks
1924–5	19,000	15,000	27,259	1·84	K.C.C.	First year of K.C.C. management.
1925–6	17,260	11,400	22,547	1·98	”	..
1926–7	31,920	26,100	54,129	2·07	”	..
1927–8	29,990	25,870	65,980	2·55	Gash Board	..
1928–9	33,173	28,037	71,007	2·53	”	..
1929–30	67,962	55,456	83,016	1·50	”	Largest flood on record; some 110,000 feddans watered.
1930–1	44,944	37,938	57,367	1·51	”	..
1931–2	23,807	17,880	30,614	1·71	”	Much land flooded in excess of cotton area.
1932–3	22,539	19,156	27,120	1·41	”	” ” ” ”
1933–4	33,693	31,146	61,365	1·97	”	..
1934–5	33,502	28,210	69,258	2·45	”	X1530—13,212; Sakel 14,988 feddans. Average yield X1530 = 3·04 kantars per feddan.
1935–6	39,069	36,257	64,495	1·78	”	X1530—12,805; Sakel 23,452 feddans.
1936–7	35,550	30,335	68,361	2·25	”	X1530—16,210; Sakel 12,281; Lecrem 1,844 feddans.
1937–8	34,432	31,850	62,534	1·96	”	X1730A—17,106; Sakel 15,495; Lecrem 1,831 feddans.
1938–9	36,518	33,292	60,922	1·83	”	X1730A—17,781; Sakel 15,511 feddans.
1939–40	26,412	24,403	51,258	2·10	”	X1730A—13,136; Sakel 9,507; N.T./2 1,760 feddans.

Notes: (i) The 1940–1 areas were reduced owing to war-time conditions. Kassala town was in enemy hands for some six months.
(ii) Sakel cotton sown between 1924 and 1934.

CHAPTER XXVI

NORTHERN PROVINCE

HISTORICAL INTRODUCTION. *By* C. B. TRACEY, 4 N, *Governor, Northern Province.*

NORTHERN PROVINCE AGRICULTURE. *By* J. W. HEWISON, N.D.A., DIP. AGR. (Reading), *Inspector Governor, Northern Province of Agriculture, Sudan Government.*

A NOTE ON THE ZEIDAB ESTATES. *By* C. B. TRACEY, 4 N.

FOR one thousand miles northwards from Khartoum the Nile winds through the desert to the Egyptian border. Excepting a few small basins, the cultivation is restricted to a narrow belt of silt irrigable by water-wheels and pumps which are at the mercy of the vagaries of the river channel. There is little doubt that in the earlier historical period the river was considerably higher in its bed, its inundation wider, the rainfall higher, agriculture much more extensive, and the population very much greater than to-day. So much so that in the second millennium before Christ this country of the cataracts formed a prosperous frontier province of the Egyptian dynasties until, in the seventh century B.C., an Ethiopian dynasty centred at Napata, near the modern Merowe, was powerful enough to conquer and hold Egypt for nearly a hundred years. Even then the effects of climatic change and desiccation were apparent, and the succeeding dynasties moved their capital southwards to the island of Meröe—the tongue of land between the Atbara and the Nile. The Meroitic Kingdom, which lasted until the third or fourth centuries of this era, had its capital at Kabbushia near Shendi. Thereafter for a thousand years the Christian Kingdom was centred at Soba near the junction of the Niles, until in turn it was destroyed by a Power from the southward—the Black Sultanate of the Fung of Sennar. The whole early history of the Sudan shows this shift of power southward before the gradual encroachment of desert conditions.[1]

The story of the last thousand years gives a picture of small riverain kingdoms resisting the inroads of Arab nomads and persistent petty wars. In the north the fragments of the Nubian Kingdom hung on persistently to their rocky stretch of river. Southwards the original inhabitants absorbed, or were absorbed into, Arab tribes invading from the north and east. The Kingdoms of Dongola and the Shaigia were formed along the great bend of the river. Around the fourth and fifth cataracts the Monassir, Rubatab, and Ababda, nomadic Arab tribes, settled on the river banks but continued a semi-nomadic life in a country not yet

[1] This should be read in conjunction with the chapter on geology and the evidence published in the Report of the Soil Conservation Committee 1944, that there has been no change in basic climate in the Sudan within historical times. The southward movement of population may have been due entirely to the lowering of the Nile in its bed, the fact of which is established. In addition there may have been a minor post pleistocene pluvial period in the northern Sudan comparable with the Nakuran wet episode of Kenya, but this has not been established.—*Editor.*

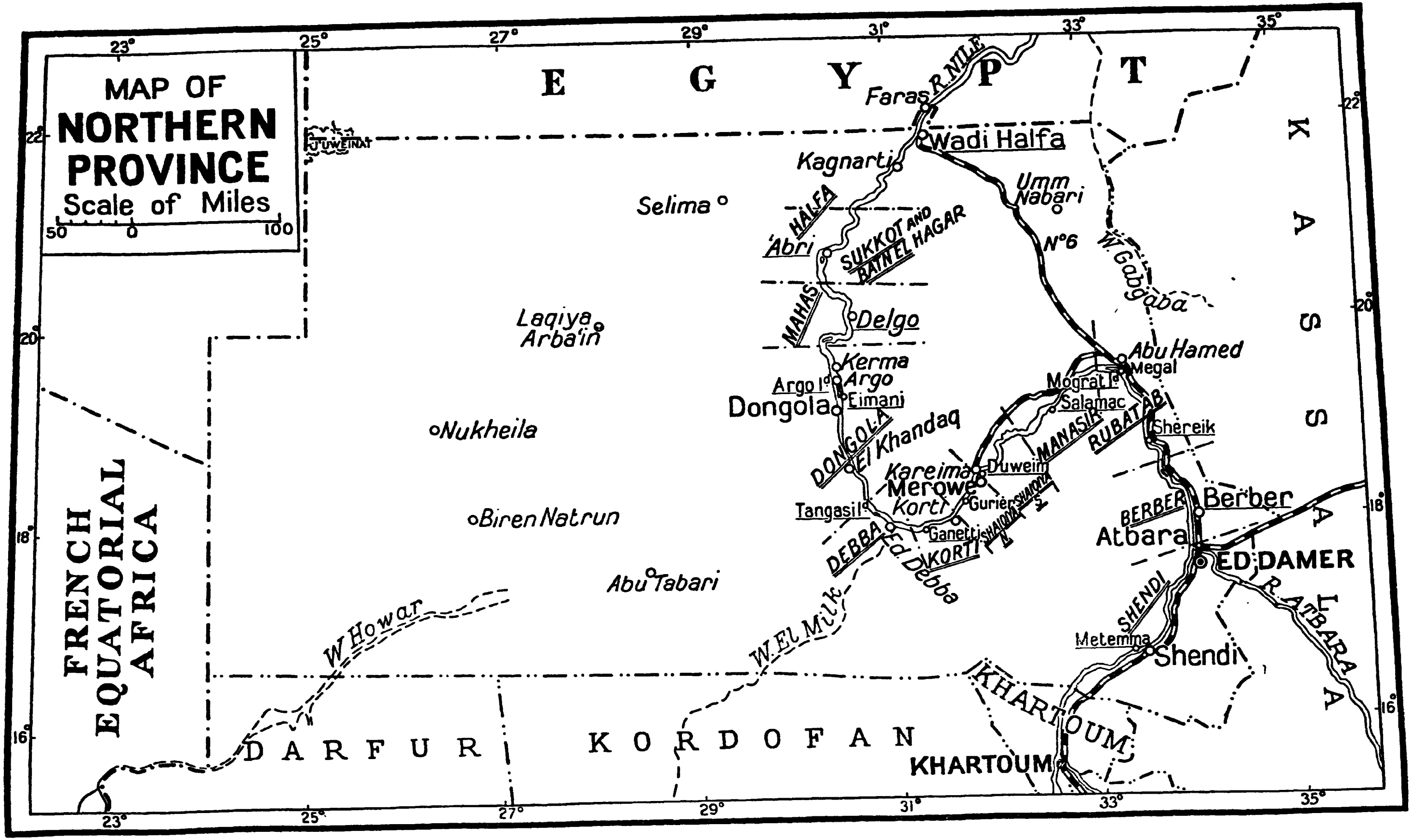
entirely denuded of bush. South of the Atbara the predominant people were the Jaalin tribe. All south of the third cataract were subject to the nominal suzerainty of the Black Sultanate. Situate on the main trade-routes between Egypt and Central Africa, the rulers undoubtedly profited from the passage of caravans, but their subsistence depended on their agriculture; and the scanty evidence that has survived shows that cultivation, especially in the Dongola basins, was more extensive than it is to-day. Slavery was the basis of their agricultural economy, and the invasion of the Sudan by Mohammed Ali's army in 1821 served only to consolidate it.

The Turkish occupation did, however, put an end to the perpetual wars: and more settled conditions certainly improved agricultural production and increased the cultivation of dates, a crop which spread southward through the Shaigia country as far as Khartoum. A Governor, Hussein Pasha Khalifa, reopened the Shendi basins by convict labour. The province capital during this period was situate at Berber, where the trade routes to Egypt and the Red Sea parted. Physical conditions, however, prevented any real prosperity and the economic centre of the Sudan lay southward of Khartoum. Already the Danagla and Jaalin turned their attention to trade and their trading slavers penetrated to Darfur, the Bahr el Ghazal and Equatoria Province.

The thirteen years of Dervish rule (1884–97) brought only disaster to this section of the valley of the Nile. Northwards from Dongola the opposing armies were facing each other, and the Khalifa's troops were billeted on the country. Southwards punitive expeditions destroyed Berber and Metemma. War, levies, and famine reduced the population to a quarter of its former strength. The number of water-wheels, the index then of agricultural production, decreased most significantly.

On the reoccupation of the country by the Anglo-Egyptian army in 1898, a spontaneous revival of cultivation occurred and continued progressively until the first European war in 1914. But pacification was accompanied this time by the abolition of slavery. For three thousand years the economy of the country between the cataracts had been founded on the slavery of the peoples of the central and southern Sudan. Abolition did not, however, immediately release all slaves, who served the land. But it cut off the fresh supply. The young men drifted away into the army, and the feudal families of the Arab tribes found their serf households dwindling, and themselves unfit for manual labour on the land. The new railways obliterated the dangerous desert caravan routes and opened easy and unimagined vistas. Already accustomed by tradition to travel and trade abroad, the people began to drift away from the land in search of the stable commerce of the new régime. Many set up in trade in the central provinces of the Sudan, many entered the service of the Government in army or office, and more still sought domestic service not only in the Sudan but in Egypt. This trend has become most apparent in the north where agricultural conditions are hardest. There only those too young or too old to go are left to till the land.[1] Once again the water-wheels have been decimated. Formerly it was by war: now it is by peace.

[1] See also the chapter on land fractionation.—*Editor.*


MAP OF
NORTHERN
PROVINCE
Scale of Miles
50 0 100
EGYPT
KASSALA
FRENCH EQUATORIAL AFRICA
DARFUR
KORDOFAN
KHARTOUM
Faras
R. NILE
Wadi Halfa
Kagnarti
Umm Nabari
No6
W. Gabgaba
Selima
HALFA
'Abri
SUKKOT AND BATN EL HAGAR
MAHAS
Delgo
Laqiya Arba'in
Kerma
Argo Id
Argo
Eimani
Dongola
DONGOLA
El Khandaq
Nukheila
Abu Hamed
Megal
Mograt Id
Salamac
MANASIR
RUBATAB
Shereik
Kareima
Duweim
Merowe
Korti
Guriei
Tangasi Id
Ganetti
KORTI
DEBBA
Ed Debba
Biren Natrun
Abu Tabari
W. Howar
W. El Milk
Berber
BERBER
Atbara
ED DAMER
R. ATBARA
SHENDI
Metemma
Shendi
KHARTOUM
J. 'UWEINAT
23°
25°
27°
29°
31°
33°
35°
16°
18°
20°
22°

Even so, nearly fifty years of security and tranquillity, consequent on two decades of devastation, have greatly increased the population. Subsistence would have been difficult, save for the faithful flow of remittances sent home by merchants and servants abroad. To a population of 600,000 remittances totalling nearly £200,000 flow annually. These are eked out by a scanty cultivation of date-trees and flood lands.

A new and modern factor, however, emerged to salve the situation—pump irrigation. Government pump-schemes started during the first world war have come to stay. Financed by trade nearly 150 private pumps are now working to help out the diminished number of water-wheels. Their finance is unstable, their cultivation sometimes uneconomic, but their produce still staves off the ultimate depopulation of the country of the cataracts.

During the period of pacification and stabilization consequent on the reconquest the country was of necessity administered closely and directly by the new Government. The area of the second and third cataracts was administered under the province of Halfa. The Kingdoms of the Danagla and the Shaigia lying between the third and fourth cataracts comprised Dongola Province. The country from the fourth cataract to the outfall of the sixth cataract formed Berber Province. With the establishment of confidence and an increasing delegation of judicial and administrative functions to the natural leaders of the indigenous peoples, it was found possible in 1935 to amalgamate the three provinces into the present Northern Province. A policy for the development of local governments is operating. Already the ancient Kingdoms of Dongola and of the Shaigia have been formed into Rural District Councils: and similar councils will be formed for the Halfa, Berber, and Shendi areas. It will be the work of these councils to develop and carry out local social services. The salvation and betterment of the agricultural resources of their meagre land is their most important function. The province no longer produces enough to feed itself and has to rely on imports of grain from the central Sudan. Without the full development of local agriculture the raising of its standard of life must inevitably lag far behind that of more fruitful zones.

NORTHERN PROVINCE AGRICULTURE

By J. W. HEWISON, N.D.A., DIP. AGR. (Reading)
Inspector of Agriculture

The higher Nilus swells,
The more it promises: as it ebbs the seedsman
Upon the slime and ooze scatters his grain,
And shortly comes to harvest.

SHAKESPEARE, *Antony and Cleopatra*, Act II, Sc. VII, l. 25.

GEOGRAPHICAL DATA

The Northern Province lies between latitudes 17° and 22° 50′ N. and longitudes 14° and 34° E., and forms a part of the great Nubian and Libyan Deserts.

The Nile valley runs in a general south-to-north direction through the east centre of the province.

Physical features

The cultivable area is restricted to a narrow strip of land on either side of the river, varying in width from a few metres to a maximum of 4 kilometres: this belt extends from the Sabaloka Gorge (sixth cataract) in the south to the Egyptian frontier, below the second cataract, in the north.

Out of a total area of 236,200 square miles, the province's agricultural land does not exceed 500 square miles. Into this a population of 600,000 people is concentrated.

Climate

In the southern part of the province the rainfall averages about 6 in. per year, and in the extreme north Wadi Halfa frequently records no precipitation for years at a stretch. Most of the rain falls in July, August, and September, but occasional local storms and showers are experienced at other times.

The shade temperature varies from a maximum in the region of 120° F. in June to a minimum of about 48° F. in January and February. On the Dongola–Halfa reach, night temperatures of under 40° are not uncommon, and frost has sometimes been experienced at Wadi Halfa.

Sand-storms frequently occur in April, May, June, and July, and these, coupled with the scorching heat, make life extremely unpleasant in the summer.

The prevalent wind between November and April is from the north; from May till October from the south. This generalization holds good for all but Halfa District, where southerly winds are exceptional.

Water Distribution

Generally speaking, rainfall plays an almost negligible role in agriculture, irrigation or inundation being necessary for crop production throughout the province. Thus it is on the height and extent of the Nile's flood that the prosperity of the people depends.

Soil: Distribution and Rough Classification

Three main types of soil are recognized by the riverain cultivators.

The most highly valued is the 'gezira' (or island) type, which is pure Blue Nile river silt of fairly recent deposition. This is extremely fertile and, with a minimum water-supply, produces heavy yields of practically all varieties of crops. In fact, good crops are frequently grown on it without resort to irrigation, capillary attraction raising sufficient moisture from the water table, which recedes as the river falls.

On analysis it reveals a surprisingly high clay content, but such is the state of flocculation that it is marvellously pliable and free working.

It is usually too rich for wheat, as unless the water table is very deep, it is impossible to control the supply of moisture, and the crop produces an over-luxuriant vegetative growth and is liable to lodge.

The second soil type, locally known as 'sãqiya' or 'qurer', occurs near the river bank on the fringe of land which is not subject to flooding at high river. This is very similar to the island soil described above, but is

silt of less recent origin. It may be classed as a rich, free-working alluvial loam, and it, too, is very fertile.

In the basins and depressions farther back from the river there occurs a soil which is usually referred to as 'karū'. This also is river borne, but having been deposited by slowly running or stationary water, the particles are very much finer and the soil heavier. This land cracks deeply when dry, is much more difficult to work, and puddles badly. When flooded annually it produces fair crops of dura, *Dolichos*, and chick peas. Under irrigation it grows good cotton and cereals (especially wheat), but it requires careful management and frequent, extended resting periods.

Land Ownership

The hinterland of the province is of little agricultural importance, being very sparsely populated by nomadic tribes which graze their herds over vast areas and cultivate only small patches of rain-grown dura for their own domestic requirements. This land is all owned by the Government, but tribal rights of grazing and cultivation are recognized.

Along the river, land ownership is a much more complicated problem. Ages of settled occupation have resulted in personal ownership being recognized, and most of the fertile land adjoining the river is registered in the names of individual freeholders.

This private ownership of land is one of the most highly prized and jealously guarded customs of the native population and is also one of the most serious handicaps to agricultural efficiency and prosperity throughout the province. By Mohammedan laws of inheritance, on a man's death his land is divided up among all his heirs: generations of this splitting up of estates have reduced individual holdings to areas that are insufficient to support a family and that are too small to justify efficient husbandry.

This brief explanation of land fractionation is all that is necessary at this stage: in the ensuing pages it will be seen that the system has a stranglehold on all agricultural advancement and prosperity.[1]

Agricultural Sociology and Policy

Before passing on to describe the agricultural practices of the province a short survey of the character, economics, and prosperity of the cultivators in general is given, so that the various problems may be understood and the attempts to overcome them appreciated.

In spite of a thin veneer of sophistication, the Northern Province farmers are some of the most conservative people in the Sudan.

The land fractionation mentioned above has so reduced their holdings that many of them are on the verge of poverty. Their diet is frequently inadequate and almost invariably unbalanced, their physique is poor, and they are therefore incapable of regular and sustained physical effort. Native custom confines their womenfolk to the precincts of their homes, and so precludes them from assisting in cultivation.

[1] See also Chapter XII on land fractionation.

The Nile has for ages been the main line of communication between Egypt and the central and southern Sudan, and this light contact with the outside world has undoubtedly influenced the character of the people. Practically everyone aspires to dealings in finance and trade, and this trait, coupled with ignorance, poverty, and an improvident nature, has given rise to a general system of mortgaging crops, often before they are sown.

Dawood Eff. Abdel Latif of the Sudan Political Service has recently investigated this practice of crop mortgage and has written an enlightening note on the subject.

He shows how the system has insinuated its tentacles through the whole strata of agricultural society in Shendi district, from the wealthiest merchants to the poorest peasants, and avers that it is reducing cultivators to a condition of serfdom.

He depicts a vicious circle of usury, on the security of agricultural produce, into which all members of the community are drawn by the fluctuating economics of an agriculture based on the Nile flood.

This, then, is the setting of Northern Province agriculture. In the foreground stands a fertile soil; an abundant supply of irrigation water; a conservative rural population, poor, under-nourished, improvident, and therefore often lazy and apathetic. In the background lurks the handicap of land fractionation and the iniquities of crop mortgage.

In 1942 J. D. Tothill, then Director of Agriculture, carried out agricultural and economic surveys in the province and made comprehensive proposals for agricultural development and administration. These proposals have since been adopted by the Governor-General's Council as a charter for agricultural policy in the province. The following quotation from Tothill's 'Note on Agricultural Policy in the Northern Province' summarizes the objectives:

'The application of this policy . . . may now be considered. Stated in a few words, the main objective . . . is to encourage the emergence of a prosperous, permanent, happy, peaceful community based upon agriculture, participating in the slow march of progress now taking place generally in the Sudan. . . . There must be an abundance and variety of good food, including fruit and vegetables, a good permanent and abundant water supply, fuel and building poles, and all the amenities that make life worth living and that are practical. Adequate communications, comfortable houses and furnishings, shops, markets, schools and medical facilities will all become part of the normal equipment of these communities.'

The application of this charter to the various types of agriculture will be discussed under the relevant sections.

Types of Agriculture

The agriculture of the province can most conveniently be considered under seven main headings, as follows:

1. Rain-grown crops in the hinterland.
2. Basin cultivation practised on depressions which are watered at the peak of the Nile flood.
3. 'Selūka' cultivation on land inundated during high Nile, and cropped as soon as the flood recedes.

4. 'Sāqiya' cultivation.
5. Pump schemes.
6. Pomology.
7. Forestry.

The divisions between the sections are not clear cut, there being considerable overlap between the various types.

Rain-grown Crops in the Hinterland

Speaking generally, the rainfall in Northern Province is insufficient to produce crops, and over the greater part of the province no rain-grown cultivation is attempted. In Shendi district, however, the rains of July, August, and September are usually heavy enough to permit the growing of about 10,000 feddans of dura in wadis and depressions, where the run-off from large catchment areas is concentrated.

After the first good soaking, quick-maturing dura seed is dibbled into the soil. Usually the land is hoed once and then receives no further attention until harvest, but the crop is dependent upon several subsequent floodings to bring it to maturity.

It is unusual for more than half the area sown to produce a crop: depredations of drought, locusts, and animal trespass accounting for the balance. The yield is normally low, anything approaching 150 kg. per feddan sown being considered a reasonable return.

This grain supplies most of the domestic needs of the Shendi nomads and often provides a surplus for sale to the riverain people.

Basin Cultivation[1]

Along the Nile, from the Khartoum boundary to beyond Dongola, a series of 'basins' have been constructed to allow the spilling of surplus flood water from the Nile on to low-lying areas alongside.

In its simplest form a basin is merely a depression watered from the river by a connecting canal. Most of them, however, are bounded by lateral banks and are divided by transverse barriers and sluices. The better ones have escape channels at the lower end and are equipped with water-regulator gates at both intakes and outlets; these allow a high degree of water control, and the regulation of the depth and duration of flooding, according to crop requirements.[2]

This system of agriculture overlaps to some extent with rain cultivation, as basins are frequently flooded by spates of rain-water from the adjacent high lands. In years of low Nile, advantage is taken of these spates to grow dura crops, but the rain-water does not bring the fertilizing Nile

[1] This, the beginning of controlled irrigation, was not known to Pliny the elder in Egypt where he describes only the more primitive 'selūka' type. He had, however, heard of it in Irak and says (Holland's translation of 1634 of the *Historia Naturae*, p. 577): 'Toward Babylon likewise and Selucia (where the rivers Euphrates and Tigris doe swell over their banks and water the country) the same husbandry is practiced,' that is, the 'selūka' type, 'but to better effect and greater profit by reason that the people may let in the water at sluces and floudgates, more or less with their own hands, according as they list themselves.' —*Editor*.

[2] For a fuller account of basin control see Chapter XXI.

silt deposits, and usually only produces inferior crops. Whenever the Nile shows promise of flooding the basins, the rain-water floods are hurriedly drained off the land via the escapes.

The main crops grown are dura and *Dolichos lablab* Linn. or 'lubia' inter-sown, and chick peas. The former requires a lighter watering than the latter and is usually sown in the higher basins and on the fringes of the lower ones. Chick peas need heavy flooding and are best sown in November, which is some 2 months after the peak of the flood. To keep the soil wet, and prevent the growth of weeds, the water is normally held in the lower basins until the end of October.

On the lightly flooded land weeds usually establish themselves strongly before the soil is dry enough to be cultivated. As soon as the land will carry animals, the grass is ploughed in, and the dura and 'lubia' seeds are sown in the plough furrows. Subsequently the land is hoed once, and sometimes twice, and the crop is then left until the dura matures. After the grain harvest the *Dolichos* is grazed off or cut and fed to 'sāqiya' bulls.[1]

Weeds (mainly *Desmostachya cynosuroides* Stapf.) almost invariably smother a proportion of the crop, and in some of the Shendi basins *Striga hermonthica* Benth. devastates the dura.

A normal yield is about 300 kg. of grain per feddan.

Chick peas or 'hummus' (*Cicer arietinum* Linn.) are usually sown on land that has been under deep water for so long that all weeds have been killed. The seeds are ploughed into the soil in November and the crop is frequently not touched again until it is harvested.

Yields vary from 300 to 600 kg. of seed per feddan. In good years extensive areas of this crop are grown, particularly in the southern part of Shendi, where the crop produces a big proportion of the revenue of the district.

These basins occupy a position of considerable importance in the economics of the province, but they are of very doubtful agricultural value. All of them are dependent upon a good Nile, and in years of low floods the areas irrigated are negligible: the following table illustrates the fluctuating nature of their usefulness:—

Area Flooded

	Shendi basins	*Dongola basins*	*Total*
1938. A very good Nile .	41,000 fed.	68,280 fed.	109,280 fed.
1941. A poor Nile . .	6,050 ,,	4,680 ,,	10,730 ,,

It is therefore quite impossible to establish any permanent system of agriculture on these basins, and they consequently have an unsettling influence on all neighbouring husbandry. It is in connexion with basin products that the iniquitous system of crop mortgage is most rampant, and the people on their fringes in southern Shendi live in a condition of squalor and poverty unparalleled anywhere else in the province.

[1] It is the custom in the Sudan to call working oxen bulls because in general it is bulls which are used for this purpose. Occasionally, however, cows, heifers, and steers take their turn at the plough or at the water-wheel.

Selūka Cultivation[1]

As the Nile flood subsides annually it leaves wide strips of moist and fertile silt which are hurriedly planted up with a variety of crops. This type of cultivation, calling for a minimum expenditure of effort, is easily the most popular in the province, and from the point of view of province economy is one of the most important. Prior to the expansion of pumping-schemes during the last few years, 'selūka' cultivation covered nearly half as big an area as that watered by all forms of irrigation.

FIG. 294. 'Selūka' land on the River Nile south of Wadi Halfa at Saras. As the river drops these lands are planted up with various food crops. Only a very limited area of land is available for crops (*photo J. F. E. Bloss*).

A wide range of food crops is grown at very little expense, the most important being millet, bulrush millet, maize, wheat, haricot beans, and barley.

In Dongola recently formed islands are usually sown initially with a form of lupin (*Lupinus termis* Forsk.) which is very tolerant of salty soil and which yields a nutritious seed.

[1] This, the oldest form of agriculture along the Nile, was thus described by Pliny about 1,900 years ago (Holland's translation of *Historia Naturae*, 1634, p. 577). 'Howbeit this is certaine, that first they cast their seed upon the slime and mud so soone as the river is downe, which commonly falleth out in the very beginning of November: which done they go over it with the plough and give it a light tilth, so as it may be covered only and lie under a small furrow. Some few there be that afterwards fall aweeding . . . but the most part after they have once sowed, and turned their seed into the ground, never after make a step into field to see how their corne groweth until they go once for all with syth on neck or sickle in hand namely at the end of March: for then they fall to reaping and cutting it down.'—*Editor.*

It is in the production of animal fodder, however, that 'selūka' cultivation makes its biggest contribution to agriculture: some 15,000 feddans of *Dolichos lablab* Linn. are sown annually, and the oxen that drive the water-wheels are almost entirely dependent upon this forage for many months of the year.

'Sāqiya' or Water-wheel Cultivation

Despite the introduction of mechanical pumps, wooden water-wheels are still the basis of agriculture in the province.

FIG. 295. A 'sāqiya' wheel at high Nile (*photo R. G. Fiddes*).

They date back to the time of the Pharaohs, and an examination of them suggests that no modern improvements have been added in the meantime. They are clumsy and inefficient, but they are understood by the people and they are locally produced, locally adjusted, and locally maintained. They, more than any other means of irrigation, fit in with the people's dogged independence and with the miniature holdings of land caused by land fractionation.

The total holding watered by a wheel is rarely more than 10 feddans, and in this, two, and sometimes three, partners participate. The area under irrigation at any one time seldom exceeds 3 feddans, and a proportion of this must perforce be fodder for the oxen.

The motive power for water-raising is supplied by oxen, usually bulls, normally working in pairs. Sufficient water can only be raised by working for long hours, usually all day with a short break at noon, and far into the night. At least two, and often three, pairs of oxen have to be kept to maintain this steady trickle of water, and on some of the Dongola water-wheels the cultivable land is so high above water level at low flood that

a double lift of water is necessary and this entails doubling the number of oxen or halving the irrigated area.

The land on which they function is immediately adjacent to the river and is usually rich silt, capable of producing heavy crops: the growing of leguminous crops for ox fodder, and the generous supply of animal manure provided by these animals, help to safeguard soil fertility; the concentration of people on such small areas ensures sufficient labour for an intensive form of hand cultivation; the difficulties of raising water mean that every drop is precious, and as a result, water control is stringent; the land is almost invariably owned by the farmers, which ensures security of tenure. Due to all these factors, combined with the experience of centuries, a system of land husbandry has been evolved which provides a bare means of subsistence for farmers, but which has kept the land in good heart in perpetuity.

The Dongola 'sāqiya' owner is by far the most respectable inhabitant of the Northern Province. Hard-working, self-reliant, and independent, his means of subsistence are pitifully meagre. His crops barely suffice to support him and his family, and leave no margin for the provision of luxuries. Usually situated far from markets, schools, and other civilizing influences, he has little contact with the outside world, and has no facilities for educating his children or for an appreciation of the amenities of life. Like the nomad Arab, he is rapidly becoming an anachronism.

Tothill in his agricultural charter said:

'It is the "sāqiya" that is the greatest source of wealth in the Northern Province, and most of the Departmental effort should be directed towards improving the lot of this community. There are innumerable features of water-wheel agriculture as practised in the Sudan that are fundamentally wrong, and we must not expect rapidly to put these things right. The deep seated cause of the poverty of the people on these lands is land fractionation, and through the inheritance laws the partition of ownership of date palms. The relief from the burdens so created will come probably through developing gradually a system ... of Government pump schemes behind the "sāqiya" strip until the stage has been reached at which freehold owners will come to recognize the disease from which they are suffering and ask the Government to purchase and reallot these lands on a Government tenancy basis. All this is over the horizon. In the meantime, there is a whole host of problems to be solved revolving round the central problem of the food supply of the people. There is a shortage of meat in the diet that should perhaps be corrected by adding soya beans and by introducing the fish tank. There is a shortage of milk, and the working oxen are eating their heads off. These problems need to be sorted out and a programme of experiments designed to alleviate the immediate lot of this very important community.'

So far only limited progress has been made towards solving these problems.

As regards the water-wheel itself several efficient metal types have been designed, but the initial cost and difficulties of maintenance make them impracticable for the rural owner. Roller and ball-bearing types have been invented to reduce the frictional loss of power in transmission: these too have proved efficacious when properly fitted and used, but they require careful fitting and lubrication, both of which are beyond the capabilities of the remote 'sāqiya' man most in need of assistance.

At Shendi a series of experiments have demonstrated the possibility of

producing good yields of soya beans by planting in July and harvesting in December, i.e. during the period when the Nile is high and water can most easily be lifted. So far, however, little success has been achieved in persuading native cultivators to grow them, even as a cash crop. The reaction to the recent Government attempt to substitute a proportion of pulses for dura in the grain ration demonstrated most clearly the conservative tastes of the local people, and proved how difficult it is going to be to persuade them to change their diet.

In 1943 the Department of Agriculture acquired a herd of 100 local cows and has started on a scheme of cattle improvement by selective breeding. The objective is to evolve a herd of cows producing a heavy yield of milk while retaining their hardiness and a high standard of physique, and so enable them to stand up to the heavy demands made on draught animals in mixed husbandry.

As soon as the required type has been fixed, and proven sires are available, stock bulls will be distributed throughout the province: these should do something towards raising the level of milk production and improving the people's diet.

There remains the ever-present problem of the land and land fractionation.[1] As Tothill said, the voluntary sale of private land to the Government for division into Government tenancies is a prospect over the horizon. Native custom and law is so bound up with land ownership that it will probably take generations of education to eradicate, while the idea of compulsory expropriation of large areas is repugnant to native opinion.

The possibility of a gradual means of approach to the problem appears to have escaped Tothill's attention. The fundamental native objection to releasing land to the Government is the loss of title and hereditary rights: hiring the land on long leases is comparatively unobjectionable, and it is along this line that the greatest progress may perhaps be expected. Already the owners of 'sāqiya' land alongside the Aliab scheme have requested the Government to lease their land and include it in the scheme for allotment on an annual tenancy basis. Admittedly the land in question is at present not irrigable by water-wheel owing to the formation of sandbanks along the river banks, and admittedly the decision to make this request was the result of 2 years' intensive Government propaganda. The fact remains that the Government has been requested to lease private land, and if the opportunity is taken, a vital precedent will have been created which may come to have far reaching effects on agriculture in the province.

The important part played by date culture in water-wheel cultivation is dealt with under the heading 'Pomology' later in this chapter.

Pumping-schemes

This type of agriculture can best be discussed under two headings, schemes installed and administered by the Government and those run by private or communal enterprise.

[1] See Chapter XII.

Government Schemes

History.[1] During and immediately after the first world war the Government opened up seven irrigation schemes in the province. They were primarily intended to increase the production of local crops and to meet the demands for fodder made by the British cavalry regiments then stationed in Egypt.

Almost all of them were sited on old basins, but they included large areas of 'sāqiya' land which were privately owned.

In size they varied from 2,000 to 4,000 feddans.

In the period between the two world wars they continued to function, the expenses of pumping and administration being met, to some extent, by the Government taking part of the proceeds of the cotton crop or a half-share of all crops grown. They were regarded as stabilizing influences and as insurances against famine in lean years, and as such were subsidized by the Government.

They were directly administered, a British Inspector of Agriculture and a retinue of agricultural police being stationed on each scheme.

And so they carried on: beacons of agricultural progress in a depressed area; setting an example in all cultural operations and land husbandry, and acquiring valuable experience and data.

No further expansion of Government projects took place until the second world war, apart from the opening of a small scheme at Debeira in Wadi Halfa district in 1935. This was intended to absorb cultivators who were being dispossessed of their lands by the raising of the water level in the Aswan Dam.

Soon after the outbreak of war in 1939 cotton growing was abandoned on all Government schemes, which then concentrated on producing a maximum output of food crops. At the same time the practice of the Government taking a share of the crop was replaced by a system of water rates, based on the cost of pumping water, and levied on all cultivators.

As the need for the Sudan to become self-supporting became increasingly evident in 1942, a big wheat-growing drive was started throughout the province, and two new schemes were hastily developed: at Aliab in 1942 and Bergeig in 1943.

These new projects were about 4,500 feddans each, and the Government, profiting from its pre-war experiences elsewhere, resolutely refused to include any privately owned land in either. Both are all Government land which permits their division into regular 10-feddan holdings, let at a nominal rent on annual tenancies.

Distribution. At present the distribution of Government schemes in the province is as follows:

	Total irrigable area
Shendi District	
Gendettu	3,000 feddans approximately
Kitiab	4,000 ,, ,,
Aliab	4,500 ,, ,,
Berber District	
Bouga	3,000 ,, ,,

[1] See also the section on pumps in Chapter XXI, commencing at p. 611.

	Total irrigable area
Merowe and Dongola District	
Nuri	3,000 feddans approximately
Gureir	2,000 „ „
Kulud	3,000 „ „
Ghaba	2,500 „ „
Bergeig	4,500 „ „
Wadi Halfa District	
Debeira	2,000 „ „

Pumping machinery. All except Bergeig are equipped with modern pumping installations driven by diesel engines: it is a striking testimony to the efficiency of our Mechanical Section that, since the inception of these schemes, not a single crop has been lost through scarcity of irrigation water or mechanical breakdown.

Rotation of crops. Proper crop rotations are prescribed by the Government and are rigidly enforced. Most of the land is on a four-course rotation:

1st year:	Summer	Dura
	Winter	*Dolichos lablab* Linn. or other pulses
2nd year:	Summer	Resting
	Winter	Resting
3rd year:	Summer	Resting
	Winter	Wheat
4th year:	Summer	Resting
	Winter	Resting

A slight variation of this rotation is practised at Kitiab, where pulses cannot be grown economically. Here a resting period follows dura in the first year and *Dolichos* is sown in the late summer of the second year.

It will be seen that a complete year's rest occurs before each straw crop. This may appear unduly extravagant, but it has been adopted as the result of years of experience, and recent attempts to intensify the cropping and narrow down the rotation at both Aliab and Bergeig have quickly demonstrated that extended uncropped resting periods are essential if the fertility of the land is to be maintained.

Cash crops and fruit culture. During the war years food crops have commanded enhanced prices, and cultivators on Government schemes have been reasonably prosperous. They have had ample food, and the sales of crops have left them a cash margin for investment or for the purchase of such luxuries as are obtainable in war-time: some of the money at least has been invested in livestock which will be an asset to the owners in post-war years. After the 1943 wheat harvest almost all the Aliab cultivators took to themselves new wives.

It has long been obvious, however, that when the present inflation of food-crop prices subsides, cultivators will be in urgent need of money and that an additional cash crop will be required. Fruit growing appears to hold out the best economic prospects, and fruit farming is therefore being introduced into the tenants' system of husbandry.

In the date belt dates are undoubtedly the most suitable fruit for this

purpose: they require little attention, the people understand their culture, and the dried fruit is easily packed, travels well, and commands a good market. Holdings on all Government schemes north of Berber are therefore being planted up with good varieties of dates. South of Berber mixed fruits, particularly mangoes and citrus, are better suited to the climate, and at Aliab and Kitiab orchards of mixed fruit are being sown on all Government-owned holdings. Each 10 feddans' tenancy will include half a feddan of grapefruit, orange, tangerines, and mangoes.

Both the date and mixed fruit-trees are supplied at Government expense and no charge on them is made to the tenants until they come into full bearing: at that stage the initial cost will be recovered in seven instalments in the form of a rent.

The growing of these crops has the special advantage of catering for a general nutritional deficiency that fruits tend to correct.[1]

Administration. As stated above, the original schemes were run under the direct supervision of departmental staff, but the present policy is to devolve management on to local farm boards, keeping the departmental staff in the background as technical advisers.

Tothill wrote:

'In the course of time it is visualized that the tenants on each Government pump scheme will form themselves into an Agricultural Society, and will elect annually a committee of management to run the agricultural community affairs of the society.

'At the present stage, however, we shall have to be content to prepare the way by setting up advisory committees that will largely be dominated by the Omdas and Sheikhs.

'These will be set up by the Governor in consultation with the Senior Inspector of Agriculture. The sooner the action can be taken the better. In the first instance the committees will probably have to be set up largely by nomination, but the principle of election is to be introduced as early as possible.

'While these Advisory Committees will at first be hopelessly inefficient, we should not despair of teaching them to be active and useful. The resident Agricultural Officer, while not a member, would be expected to help them in every possible way and maintain regular contact with them. The Inspector would also do his utmost to help them to become useful to the community. They should be encouraged to keep a record of their proceedings in a book.

'In the final stage, when the committee has become a managing committee for the society, there will be neither an Inspector nor an Agricultural Officer resident on any pump scheme. The Government will remain as friendly landlord and as the provider and distributor of water, and will provide only such staff as is necessary to keep the pumps running, the canals operating, and the books as between landlord and tenant straight.'

The Wadi Halfa scheme at Debeira has been administered by a Farm Board from the beginning, and although it cannot be claimed that the management has been conspicuously efficient, it has at least kept the scheme running and regularly collected the water-rates from cultivators.

At Aliab and Bergeig farm boards were set up at the inception of the schemes and are gradually assuming their appointed responsibilities.

Elsewhere boards have either been set up or are in the process of being appointed, but in some places clashes of personalities are likely to handicap their activities for a considerable time.

[1] For details see Chapter XIV on Nutrition.

Since the passage quoted above was written in 1942 responsible Government opinion has been modified slightly in one respect. It has now been decided that farm boards should be purely executive bodies, concerned exclusively with scheme management and finance, and unrelated to the Native Local Government Administration. For this reason the personnel of the boards now being formed are selected from actual tenants on the schemes and are not being 'largely dominated by the Omdas and Sheikhs' as was at first suggested.

Cultivators' standard of living. Mr. W. F. Crawford, Governor of the Northern Province until 1944, and a very keen agriculturist, wrote in the province *Handbook*:

> 'These Government pumping schemes are the finest agricultural assets possessed by the province. They are the best insurance against famine and distress in years of low Nile. Everything on them is better than outside. Babies are fatter, cattle stronger, and the land better tilled.'

Descriptions of typical holdings on Aliab and Bouga will give an idea of the tenants' mode of life and standard of living.

Aliab. At Aliab each tenant has a 10-feddan holding, of which half a feddan is reserved for his house, vegetable garden, compost pit, &c., and half a feddan for his orchard of citrus and mango trees.

He and his family normally occupy a mud house of standard design, simple but adequate for his needs. His animals—usually a pair of working bulls, a milch cow, some goats, and a donkey—also live on the holding. The garden plot supplies him with vegetables, grown according to his own desires. The half-feddan of fruit orchard has only recently been planted and will yield nothing for several years but will eventually provide him with fruit for domestic use and at the same time bring him in a substantial financial revenue.

The remaining 9 feddans of his plot are at present divided into three equal parts, on which he grows 3 feddans of wheat, 3 feddans of dura, and 3 feddans of *Dolichos* each year.

An average return from these crops is 1,580 kg. of wheat and 1,360 kg. of dura. Of this about 220 kg. of wheat and 680 kg. of dura are retained for home consumption; these quantities generously supply the staple diet of a family of six persons for a year.

After making provision for the next year's seed requirements, the sale of the balance of these crops at present prices yields just over £E.30.000 m/ms. In addition, surplus vegetables, clarified butter made by his wife, sheep, goats, or cattle raised on the holding, and illicit sales of dura straw, are calculated to bring in a further £E.10.000 m/ms., making his gross annual revenue about £E.40.000 m/ms.

From this he has to pay £E.20.400 m/ms. in water-rates, £E.2.100 m/ms. in land tax, and some £E.3.000 m/ms. for hired labour at rush periods.

His net cash income is therefore only in the region of £E.15.000 m/ms. per year, but he and his family and livestock are provided with a generous mixed diet.[1] If the value of the produce consumed by the family is taken

[1] The fundamentally important question of tribal nutrition is discussed in Chapter XIV and some of the problems involved in Chapter XII.—*Editor.*

into consideration, his holding is worth somewhere about £E.36.000 m/ms. per year to him.

At present practically all the surplus £E.15.000 m/ms. is spent in the black market on purchases of tea, sugar, and clothes at somewhat extravagant prices, and between harvests he is penniless. It is the local habit to be penniless between harvests but to lay in stocks of commodity goods when cash is available, and normally the £E.15.000 m/ms. enables the household to clothe itself adequately and to purchase luxury items such as tea, sugar, and tobacco in reasonable quantities.

FIG. 296. Birds of several species do great damage locally and seasonally to dura. This type of bird scare is used in the Northern Province (*photo R. G. Fiddes*).

Taken on the whole his life is far from strenuous. To keep his holding in good order he is required to contribute about 270 man-days work per year, of which some 90 days are on animal cultivations, normally performed by his small sons. This means that a cultivator is fully occupied for about 4 hours per day and his sons for 2 hours: this is just about enough to keep the average Northern Province cultivator reasonably happy, out of mischief, and to allow him to complain that he is grossly overworked.

The fodder produced by the *Dolichos* and the dura straw is ample to maintain his animals in good condition.

The above figures are based on the three-course rotation still practised at Aliab, but the results of this intensive cropping are reflected in the small yields of crops grown. The rotation is likely to be changed shortly to the standard four-course, which will reduce the area of each annual crop from 3 to 2¼ feddans. The improved soil fertility resulting from the widening of the rotation may be expected to produce increased crops to compensate for the reduced areas.

Bouga. Bouga is an old-established scheme which has benefited from twenty years of direct administration and close British supervision,

and where agricultural efficiency has not been hampered by the teething troubles which must inevitably accompany devolution of responsibility to farm boards.

The Takawin tenants of the Government holdings at Bouga are undoubtedly the best cultivators and the most stable community in the province. Most of them have been resident on their holdings since the early nineteen-twenties and have acquired a technique which enables them to produce their crops, husband their livestock, and maintain their holdings in good condition, with a minimum of effort.

They too occupy 10-feddan plots, but their land is worked on the four-course rotation and each holding is planted with 1 feddan of 'Mishrig' dates which occupies an integral part of the cropping area. These dates will shortly come into full bearing and are confidently expected to yield an average of 2½ tons of dates per feddan annually. At present prices this would be worth about £E.50.000 m/ms.

In addition to the dates, each cultivator grows 2½ feddans of wheat, 2½ feddans of dura, and 2½ feddans of *Dolichos* each year. Because of the wide rotation and a higher standard of cultivation—achieved by years of experience and training—these areas produce crops at least equal to the Aliab yields from 3 feddans.

The Bouga cultivators' cash income is therefore very similar to that of his Aliab contemporary, but the Bouga families, having been longer established on their holdings, have worked out a far more efficient system of domestic economy. At Bouga also, the date gardens will start yielding cash crops almost immediately, whereas at Aliab the mixed fruit orchards cannot be expected to contribute to the tenants' income until 1950 at the earliest.

Land ownership on Government schemes. The above illustrates the condition of typical tenants on Government holdings. It most certainly does not apply to cultivators of private land on Government schemes. The condition of affairs on the southern end of the Gendettu scheme completes the picture.

There practically all the land is freehold and consists of irregular-sized holdings, varying from a fraction of a feddan to estates of considerable extent.

Most of the larger holdings are let at exorbitant cash rents, or are cultivated by working partners who provide all the labour and pay a half-share of the crops to the landlords. The tenants have no security of tenure and are therefore only interested in exploiting the land. In fact, rents are so high, and holdings so small, that it is wellnigh impossible for a tenant to earn a bare living and at the same time make any provision for keeping the land in good heart.

It is impossible for the Government to evict bad cultivators, and the system of letting and subletting land so complicates responsibility that reasonable standards of efficiency and water discipline are practically unattainable. All cultural operations are performed most perfunctorily and are nearly always late.

As a result of poor farming, crop yields are low, and the standard of living of the people compares most unfavourably with that of tenants on Government land.

This unsatisfactory state of affairs has long been recognized, but the remedy of expropriation and reallocation in tenancies capable of supporting prosperous farmers, and of providing alternative livelihood schemes, would still be unpopular, and this comparatively simple and almost ideal remedy cannot yet therefore be adopted.

Short of the compulsory buying out of the freeholders, an alternative remedy would appear to lie in the Government renting these lands on long leases. A request of this kind has come from the cultivators on the privately owned lands of the Gendettu pump scheme for their holdings to be rented to Government, initially for 7 years, and for Government to reallot the land in suitable plots. Should it be possible to reach agreement on these lines, the system might well be extended to other areas.

General. The area occupied by Government schemes represents only a very small part of the agricultural land in the province, but their importance is out of all proportion to their extent.

As demonstration areas alone, they play a most important role. They lead the way in all agricultural progress and are valuable centres for the dissemination of improved varieties of crops and official propaganda. With few exceptions they are permanent settlements of prosperous tenants, practising a high standard of mixed husbandry, living on the land and by the land.

Private Pump Schemes

The private pump schemes are a comparatively modern development. Soon after the end of the first world war a few foreigners acquired estates in the province and opened up pumping-schemes: these were mainly ambitious financial ventures which had to close down in the years of agricultural depression between the wars.

The one outstanding exception is the Zeidab estate, which was originally opened as a settlement for released slaves from North America soon after the reconquest of the Sudan. It was eventually acquired by the Sudan Plantations Syndicate as a cotton-growing project and as such has continued to function. It is much the biggest irrigation scheme in the province and differs so radically from either Government or private pumps that it merits a special note, which is included at the end of this chapter.

Most of the other estates were purchased by local Sudanese at almost nominal prices, and these formed the nucleus of the private scheme organization in the province.

By 1937 there were 77 such schemes operating, but by 1943 their number had increased to 147, the sudden rise being largely due to the incentive of increased prices of food crops. In Merowe and Dongola they are still increasing, but at Shendi there have been no important recent additions.

These schemes are financed and operated by private or communal enterprise for a variety of reasons. Many local notables consider it increases their prestige to own schemes. The high war-time prices of food crops have attracted many of the merchant class to agriculture, in the belief that they can—with no previous experience—amass fortunes from the land. Both of these types usually make thoroughly bad scheme

owners. Neither has any real interest in farming, and neither is prepared to do anything more than exploit the soil and the peasant farmers.

Time-expired officials are showing an increasing tendency to embark on agricultural ventures on their retirement from Government service. Some of these are genuinely interested and run very good schemes.

A few schemes are in the hands of business-like farmers, real lovers of the land, who have enough commercial acumen to enable them to manage their estates efficiently. Unfortunately, this type is rare.

Finally there are the agricultural co-operative societies in Merowe and Dongola which derive most of their capital from investments by local men engaged in lucrative employment in Egypt.

In many cases the scheme owners themselves farm part of the land, but, in the main, they merely act as water providers to private tenants, who contribute half the crops produced in return for water supplied.

Both diesel and steam engines are employed to drive the pumps. In Merowe and Dongola most of the more efficient schemes are equipped with modern diesel plants, but in Shendi steam engines predominate. All of these steam plants are obsolescent, most of them would be considered obsolete anywhere else in the world, and a few of them are museum pieces. Their consumption of wood fuel is prodigious, and they are rapidly denuding the country-side of what little timber exists in the province. This depredation of forests has only been tolerated because of the urgent need for food crops.

During the second world war they have been employed exclusively on the production of food crops. Wheat has been grown throughout the province; in Merowe and Dongola it has been the main crop, but considerable areas of Egyptian beans (*Vicia faba* Linn.) and peas have been cultivated. In Shendi haricot beans have been the most popular crop, but extensive areas of wheat have also been sown under compulsion.

Few of them follow any strict rotation of crops and most of them continuously use the land most easily irrigated until it is played out. This applies particularly to the Shendi steam pumps, most of which are operated by merchants in search of quick profits; the better schemes equipped with diesel engines are much more static and have been largely confined to the environs of their pumps, but even they, in many cases, have been guilty of land exploitation.

Generally speaking, rotations are acceptable to neither the scheme proprietors nor the land-owning cultivators. The former object to them as they entail additional capital expenditure on canalizing land to provide for resting periods, the latter dislike to see part of their land lying idle when it might be producing crops.

The standard of cultivation varies greatly. On a few of the Dongola schemes it approaches that on privately owned land of Government pumping schemes; the vast majority however, including practically all the Shendi ones, can only be regarded as temporary projects, exploiting the present high prices and making little contribution to the permanent prosperity of the province.

The Dongola co-operative schemes are worthy of special mention. These are run on communal lines and are administered by committees

elected from the shareholders and cultivators. Meticulous accounts are kept, which are regularly scrutinized by qualified auditors approved by the Government. In fact, their financial management leaves little to be desired: the agriculture practised on them, however, does not attain the same high standard of efficiency.

During the war they have prospered exceedingly; they have shown good profits which they distributed philanthropically and, more important, they have accumulated substantial financial reserves. How well they

FIG. 297. Date-palms damaged by inundation near Wadi Halfa (*photo F. Crowther*).

will be able to stand up to periods of depression remains to be seen, but their reserves of capital should place them in a position to tide over hard times for a number of years.

The province agricultural policy note reads as follows on the subject of private pump schemes:

> 'The owners of these schemes need all the help that can be given in the way of advice and neighbourly assistance, and the schemes should be visited as routine by the appropriate Agricultural Officers and Inspectors. Tenants on such schemes have the right to be treated as well as those on the Government schemes, and visiting staff should at all times pay particular attention to this point. There is need for committees on some of these schemes to serve as a link between the tenants, and the owners, and the Government.'

For the past few years they have been regularly visited as suggested above, and advice has been proffered to them lavishly, but the owners and cultivators alike are so exclusively concerned with making money while the going is good that in the majority of cases advice is wasted on them.

A few of them are developing on the right lines, but the best that can be said for most of them is that they have made a useful contribution to the war-time food production drive.

Possibly half of them will continue to flourish in normal times, but the future of the remainder is, at the best, obscure.

Pomology

This subject is dealt with comprehensively in Chapter XVI on crops and all that is attempted here is to indicate how fruit culture fits into the general agricultural economy of the province.

'Sāqiya'

In the three Northern districts date culture figures prominently in 'sāqiya' farming and is usually the chief cash crop. Wheat and dura are grown for home consumption, and fodder crops for the oxen, but the cultivators' only cash income is derived from the sale of their dates.

Some areas specialize in high-class varieties of palms; probably the best instance of this is the Abu Hamed production of 'Mishrig' soft dates. Taken on the whole, however, there is far too big a percentage of self-seeded trees ('gow') which greatly detracts from the value of the produce. The Pomology Section is doing everything possible to demonstrate the value of superior varieties, but in areas where date palms are jointly owned, any large-scale improvement is almost impossible.

Pumping Schemes

The introduction of fruit orchards into Government pump schemes has been mentioned above.

In the last few years several private pump-owners have invested considerable sums in developing orchards of mixed fruit-trees, either as specialized projects or as integral parts of schemes practising general cropping.

Small pumps irrigating fruit orchards are becoming increasingly popular as hobbies for retired Government officials.

Forestry

There are two central forest reserves in Shendi district, both on 'basin' land. These are being cut at present for fuel for the private steam pumps.

In addition, there are three fairly extensive unclassified forests in the Dongola basins. The largest of these, Kerma, is being cut to provide fuel for the steam pumps of the Government scheme at Bergeig: these Bergeig steam-engines will shortly be replaced by diesels, so their depredations on the forests will not continue indefinitely and, in any case, the land cleared is being reafforested.

To preserve the scanty timber of the province, the Nile Pumps Control Board has recently enacted that all steam-driven pumps in the province must be replaced by oil-burning installations within the next 2 years. The pumping licences of any scheme owners who fail to effect this replacement will be automatically cancelled.

Much the most important commercial forestry activity in the province is the trade in 'dōm' palm (*Hyphaene thebaica* Mart.) products. Most of these forests are on the river Atbara, but there are also extensive areas of them in the north of Berber district.

The fruits are processed to produce vegetable ivory, chiefly for button

manufacture, and 'dōm' palm timber also provides a large part of the building material used in the province.

Almost all Government pump schemes now have forestry plantations of neem, eucalyptus, and mahogany, which are intended to provide cultivators with fuel and timber poles.

At present they are maintained directly by the Government, but as the management of the schemes is gradually devolved to the local farm boards, the latter will assume custody of the plantations.

Agricultural Policy

In the foregoing pages reference has constantly been made to Tothill's 'Note on Policy'.

In 1944 His Excellency the Governor-General in Council approved the formation of a Northern Province Agricultural Committee with the following terms of reference:

1. To review at regular intervals and not less than once a year the execution of the agricultural policy for Northern Province as stated in Tothill's note, and to report thereon to the Director of Agriculture and Forests for submission by him to the Central Government.
2. To consider and make recommendations to the Director of Agriculture and Forests on the ways and means of furthering the execution of the above policy with a view to improving the social and agricultural standards throughout the province.
3. To advise the Director of Agriculture and Forests generally on agricultural questions arising in the province.

The Committee is composed of the following members of the province staff:

Governor Northern Province (*Chairman*).
Deputy Governor (*Vice-Chairman*).
Senior Inspector of Agriculture.
Inspector of Pomology.
Province Medical Inspector.
Province Veterinary Inspector.

It has powers to co-opt outside persons (such as District Commissioners, Inspectors of Agriculture, Irrigation Engineers, Local Government Heads, owners of private pump schemes) on questions where their opinion is needed.

The first general meeting, held in December 1944, considered progress reports by the Senior Inspector of Agriculture and the Inspector of Pomology on the implementation of the prescribed policy. These reports showed that considerable progress had already been made along the lines of widening the scope of departmental activities, reallocating Government lands on Government schemes, the setting up of farm boards, livestock improvement, and the establishment of pole plantations. It was pointed out, however, that shortage of staff had prevented any appreciable

progress on the improvement of 'sāqiya', 'selūka', and basin cultivation. The problem of land ownership and fractionation had not yet been tackled.

THE FUTURE OF NORTHERN PROVINCE AGRICULTURE

Taken on the whole, the future prospects of agriculture in the province are not bright.

It seems unlikely that 'sāqiya' cultivation can survive for long in an age of advancing civilization. The mechanics of the water-wheel are so crude that, despite the low standard of living of its operators, it cannot continue to compete indefinitely with modern mechanical efficiency.

Conservative though the 'sāqiya' cultivators are, the general spread of education is bound to influence the rising generations and make them demand a less tedious and more prosperous life.

It appears obvious that the water-wheel is doomed,[1] but what is to replace it is not yet clear.

Private pump schemes in their present state certainly offer no alternative. The absence of potential proprietors willing to give the land and their cultivating partners a fair chance precludes any possibility of these projects providing a settled and reasonably remunerative means of livelihood for a large section of the community.

In any case, the obstacles of private ownership of land, land fractionation, and crop mortgage prevent any rational development along the lines of private enterprise.

It appears that the only real hope for the province's agriculture lies in the combination of fruit culture and Government pump schemes, working on land freed from private ownership.

Finally, a word about the Zeidab scheme which occupies a special place in Northern Province agriculture.

THE ZEIDAB SCHEME

By C. B. TRACEY, 4 N.
Governor of Northern Province

In 1904 an American philanthropist, Leigh Hunt, received an option from the Sudan Government over an area of about 11,000 feddans along the river at Zeidab. His intention was to settle American negroes on the land there. He had another site at Burri by Khartoum. The project was a failure. Among other factors the climate did not suit the negroes. A company formed in England, under the title of the Sudan Experimental Plantations Syndicate Ltd., acquired the option land from Leigh Hunt with all his rights, interests, and obligations. In 1907 a new agreement was made with the Government and the title was changed to the Sudan Plantations Syndicate.

[1] Perhaps I am old fashioned but the obsequies do not appear to me to be in sight. My gardener daily uses an iron version of the neolithic sickle and a plough very similar to that of Dynastic Egypt is still in wide use in India and northern Africa.—*Editor.*

The first manager was Mr., now Sir Alexander, Macintyre, and Zeidab became the first modern cotton concession in the Sudan and by its experimental work fathered the Gezira Scheme.

During the first European war temporary extensions were made for the production of wheat. After the war in 1923 the land was purchased from the Government. An extension of some 4,000 feddans was purchased in 1929, and further areas were leased until 1939, when the total area of the scheme reached 23,600 feddans.

The crop is of high-grade American type and the company has erected its own ginning factory beside its pumping plant which consists of four diesel engines with an output of 1½ tons per second.

The total area under cotton is 15,000 feddans. On the company's freehold land and the leased land the rotation is one-third under cotton and two-thirds resting. On the native-owned land the proportion is a half.

The terms of tenancy stipulate that the company takes one-half of the value of the cotton crop as water-rate and rent. The tenant pays all expenses of cultivation, including the cost of ploughing when it is carried out by the company's diesel ploughing plant. In addition the tenant obtains free water for his grain areas. On the Syndicate land the proportion between cotton and grain is as 10 is to 3: but on Government leased land the proportion is as 10 is to 5. Individual cotton holdings vary in size but, in the main, Syndicate land is divided into holdings of 10 feddans and Government land into holdings of 5 feddans.

In addition, in years of low river and during the war when food production was of paramount importance, the company has provided water at a nominal rate to native land owners adjacent to the scheme. This area is considerable and has proved a most valuable addition to local food resources.

This scheme with its efficient management has had a continuous life of nearly 40 years. Although its accounts are not published, it is to be assumed that it has been a profitable enterprise, and it is perhaps the sole standing proof (for the Government schemes are subsidized)[1] that irrigation in Northern Province is a commercial proposition.

[1] This was true for a long period up to about 1941, when these schemes were overhauled and fruit substituted for cotton as the main cash crop. When the trees come into bearing the schemes are expected to pay their way.—*Editor.*

CHAPTER XXVII

BLUE NILE PROVINCE

By E. MACKINNON,[1] 4 N, B.SC. (Agric.), *Asst. Director of Agriculture*

'You dare not make war on cotton. Cotton is King.'—JAMES H. HAMMOND, Speech, U.S. Senate, March 1858.

GENERAL REMARKS

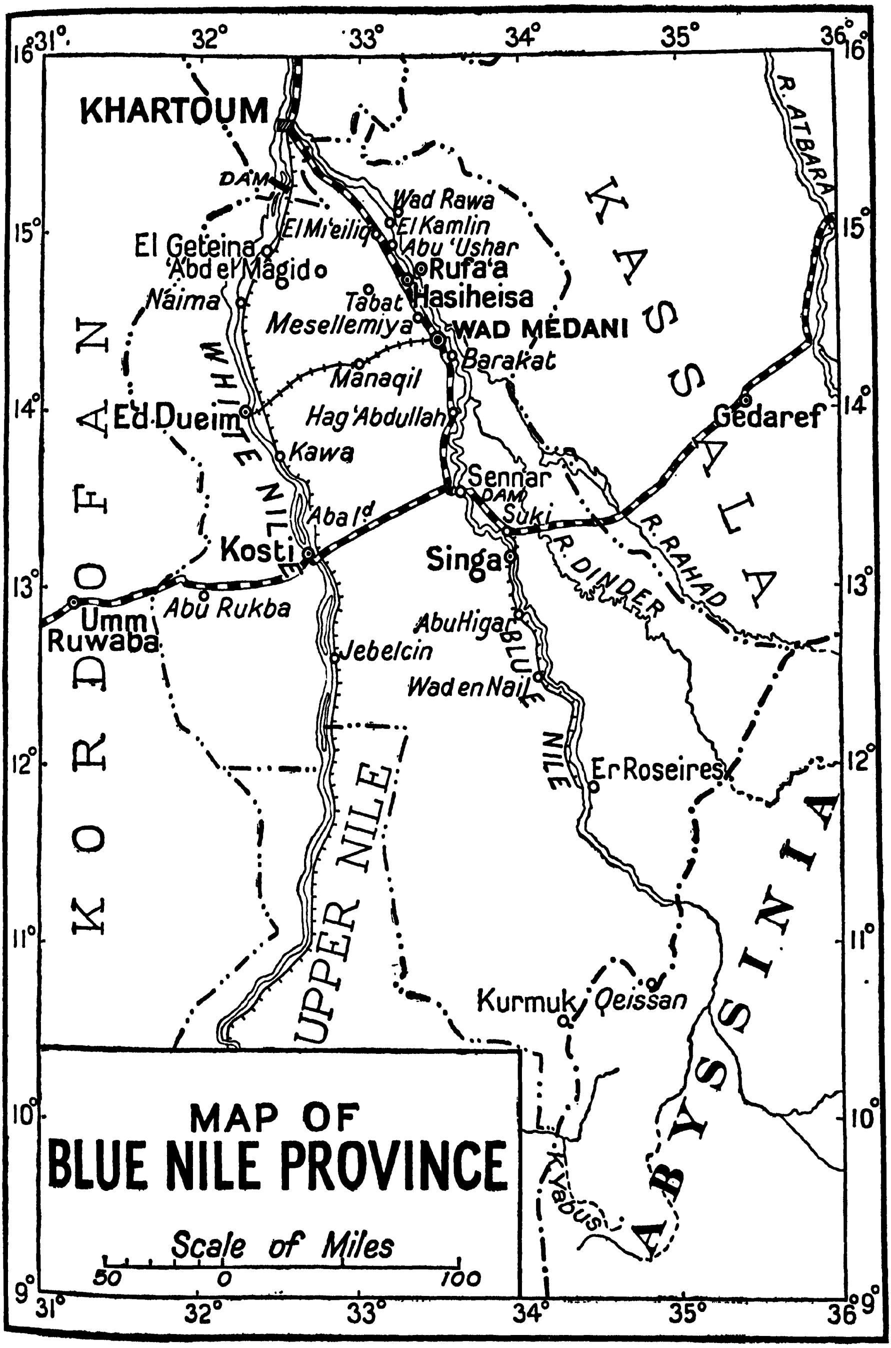
Area, Population, Administration, &c. (as at 1940)

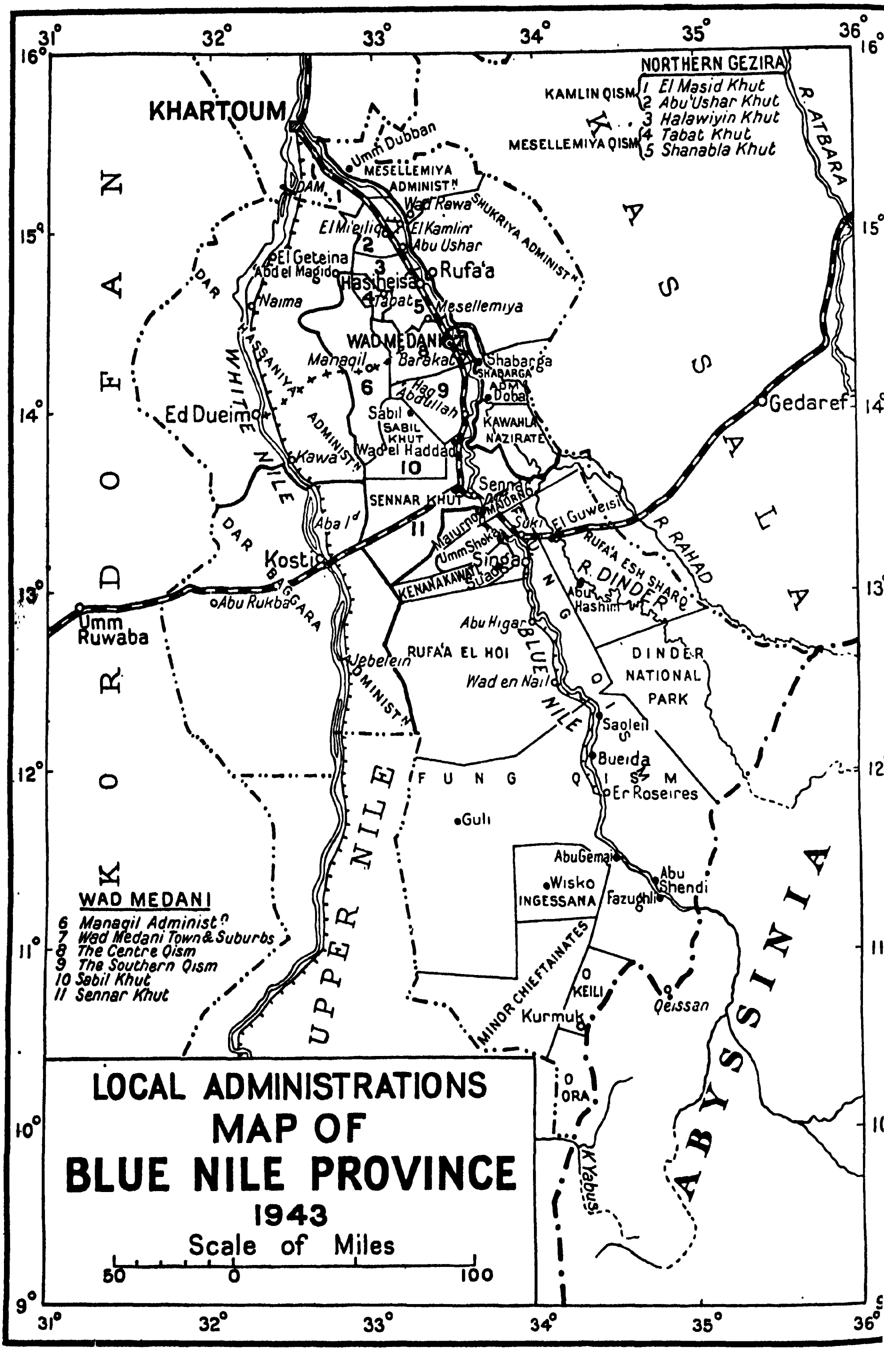
Districts	*Area sq. miles*	*Approx. population*	*Government stations, &c.*
Rufa'a . . .	5,535	171,657	Rufa'a (District H.Q.). Wad Rawa (Police Post).
Hasiheisa . .	1,550	127,250	El Hasiheisa (District H.Q.). Police posts: Tabat, Meselemiya, Mi'eilig, Masid.
Wad Medani . .	4,975	415,574	Wad Medani (Province and District H.Q.). Sennar (Sub-district). Police posts: Managil, Hag 'Abdullah.
Fung . . .	25,995	296,034	Singa (District H.Q.). Roseires (Sub-district). Kurmuk (Sub-district). Police posts: Suki, Queissan, Wisko, and Dinder Game Reserve.
Ed Dueim . .	7,560	219,754	Ed Dueim (District H.Q.). Police post: Abu Guta.
Kosti . . .	9,160	180,216	Kosti (District H.Q.). Police post: Jebelein.
Total . .	54,775	1,410,485	

Wad Medani, the chief town, has a population of approximately 40,000. The province has been formed by the amalgamation of the old provinces of Blue Nile, Fung (originally Sennar), and White Nile. The latter was only finally included in 1939, and the composite province was named 'Gezira Province'. After two years a reversion was made to the title of 'Blue Nile Province' for the amalgamated area.

Formerly the following places were sub-district headquarters with a resident British political official: El Geteina (White Nile), El Kamlin (Blue Nile), Old Sennar (Blue Nile). Mamurs were also previously posted, within fairly recent dates, at: Kawa (White Nile), Manāgil (Gezira), Hag 'Abdullah (Blue Nile), Karkoj (Blue Nile), Wisko (Darfung), and Abu

[1] I wish to acknowledge the considerable help received from many members of the Department of Agriculture and Forests and of the Political Service. In particular I wish to thank the following who have read and checked the early drafts: Mr. G. R. F. Bredin, Governor B.N.P.; Mr. W. N. Allan, Irrigation Dept.; Mr. F. A. Fowler, Senior Inspector of Agriculture, B.N.P.; Mr. A. Gaitskell, Sudan Plantations Syndicate; Mr. J. W. Cummins, Finance Dept.—E. M.


KHARTOUM
DAM
Wad Rawa
El Kamlin
El Mi'eiliq
Abu 'Ushar
El Geteina
'Abd el Magid
Rufa'a
Hasiheisa
Tabat
Naima
Mesellemiya
WAD MEDANI
Barakat
Manaqil
Ed Dueim
Hag 'Abdullah
Kawa
WHITE NILE
Sennar
DAM
Aba Id
Suki
Kosti
Singa
Umm Ruwaba
Abu Rukba
AbuHigar
Jebelcin
Wad en Nail
BLUE NILE
Er Roseires
UPPER NILE
Kurmuk
Qeissan
Kyabus
R. ATBARA
R. RAHAD
R. DINDER
Gedaref
KASSALA
KORDOFAN
ABYSSINIA
MAP OF
BLUE NILE PROVINCE
Scale of Miles
50 0 100
31° 32° 33° 34° 35° 36°
16° 15° 14° 13° 12° 11° 10° 9°


LOCAL ADMINISTRATIONS
MAP OF
BLUE NILE PROVINCE
1943
Scale of Miles
50 0 100
KHARTOUM
NORTHERN GEZIRA
KAMLIN QISM
1 El Masid Khut
2 Abu Ushar Khut
3 Halawiyin Khut
MESELLEMIYA QISM
4 Tabat Khut
5 Shanabla Khut
WAD MEDANI
6 Managil Administ^n
7 Wad Medani Town & Suburbs
8 The Centre Qism
9 The Southern Qism
10 Sabil Khut
11 Sennar Khut
KORDOFAN
KASSALA
ABYSSINIA
UPPER NILE
WHITE NILE
BLUE NILE
FUNG QISM
DAR HASSANIYA ADMINIST^N
DAR BAGGARA
MESELLEMIYA ADMINIST^N
SHUKRIYA ADMINIST^N
RUFA'A EL HOI
RUFA'A ESH SHARQ
DINDER NATIONAL PARK
INGESSANA
MINOR CHIEFTAINATES
KEILI
ORA
R. ATBARA
R. RAHAD
R. DINDER
K. Yabus
Wad Medani
Rufa'a
Hasaheisa
Sennar
Singa
Kosti
Ed Dueim
Gedaref
Umm Ruwaba
Er Roseires
Kurmuk
Qeissan
Fazughli
Abu Shendi
AbuGemai
Wisko
Guli
Bueida
Saoleil
Wad en Nail
Abu Higar
Jebelein
Abu Rukba
Aba I^d
Kawa
Wad el Haddad
Sabil
Managil
Barakat
Shabarga
Doba
KAWAHLA NAZIRATE
SENNAR KHUT
Suki
El Guweisi
Abu Hashim
KENANA KAWAHLA
Umm Shoka
Naima
El Geteina
Abd el Magid
El Mieiliq
El Kamlin
Abu Ushar
Wad Rawa
Mesellemiya
Tabat
Umm Dubban
DAM
Hag Abdullah
SHABARGA ADM
Suad
31° 32° 33° 34° 35° 36°
16° 15° 14° 13° 12° 11° 10° 9°

Hashim (Dinder). Amalgamations, improvement of transport, and the spread of settled conditions have led to a reorganization of the staffing required in many places.

The area lying between the two Niles is known as the Gezira (meaning island or peninsula); its southern boundary is rather vague, but the Sennar–Kosti railway line is now regarded as the southern limit for practical purposes.

Historical Summary

From the end of the fifteenth century until early in the nineteenth, the area included within the present province boundaries was under the Government of the Fungs. The first Fung Sultan, Amara Dongis, commenced his rule in 1485 and had his capital at Sennar, on the Blue Nile. The dominions controlled by the Fung kings were known collectively as the Sultana Zarga (Black Sultanate), and by the beginning of the sixteenth century were of considerable extent, including Kordofan to the west and Dongola to the north. The former southern boundaries are uncertain, but the tribes to the east, as far as the Abyssinian frontier, were all tributary to the Black Sultanate. In 1699 Sennar was a town of nearly 100,000 inhabitants with a considerable trade, chiefly in cotton. Burckhardt, in 1814, remarked that Sennar cotton cloth (damur) was used for clothing in Kordofan, Dongola, and eastwards as far as the Red Sea.

By this time the Fung Sultanate was in its dotage, and the kingdom fell an easy prey to the Turko-Egyptian forces under Ismail Pasha in 1821. Under Egyptian rule the Gezira, as far south as Wad Medani, was included in Khartoum Province. Taxation was heavy and oppressive, and the slave-trade, centred on Mesellemiya, was a flourishing concern. Gessi Pasha estimated that more than 400,000 women and children were sold into slavery between 1860 and 1874, and Sir Samuel Baker reckoned the annual figure to be at least 50,000 during the years preceding 1869. During the Mahdist rebellion most of the Gezira tribes followed Ahmed Wad Ali el Ta'eishi under the 'black flag' of Yagoub. The Turko-Egyptian garrison at Sennar held out for a long time, but the town was finally captured in 1885 by the Mahdist forces.

During the Mahdia the Gezira was a centre for the grain supply for the Khalifa's army and for the crowded population at Omdurman. In 1886 the inhabitants of the Gezira were summoned to Omdurman, and so this area was largely deserted. Owing to the difficulty of feeding so many people the Gezira tribes were allowed to return in 1888, a year of great famine. After the reconquest of the Sudan in 1898 the district settled down to stable political conditions.

The development of the Gezira plain as an irrigation project is discussed more fully elsewhere. A survey of the land involved and a settlement of the rights of landholders were essential preliminaries before any full details could be worked out. Survey work was therefore put in hand forthwith, and land settlement was started in 1906.

The second step taken was the extension of the railway line to Sennar during 1909–10. The third stage in the process of development was the initiation of stations to test out the possibilities of irrigation by pumping

from the Blue Nile, and, from these earlier experimental stations, the Gezira Irrigation Scheme has been expanded in stages to its present proportions. The construction of the Sennar Dam was held up by the 1914–18 war, and it was not till 1925 that irrigation by gravitation water was possible.

Physical Features

The Gezira, a flat clay plain with a general slope from south to north as well as from east to west, composes the bulk of the province. Isolated rocky hills occur along the Sennar–Kosti line, and a few similar outcrops are found on the plains sloping to the Blue and White Niles. South-west of Roseires the Tabi Hills form a low massif, with scattered isolated hills radiating from it. From this point the hills increase till the Abyssinian foothills are reached at Kurmuk, which lies on the border. The western part of the province trends into the low sandhill or 'qōz' so typical of north-eastern Kordofan. The province is intersected by the Blue and White Niles; the former is fed by two tributaries, the Rahad and the Dinder, which join the main river near Wad Medani. Both these streams have very tortuous channels and flow only during the rainy season, drying out to a series of pools during the hot months. There is a marked contrast between the Blue and White Niles. The former is navigable by steamer as far as Roseires during high Nile and only to a very limited extent at low river, has a well-defined channel with a marked bed-slope, has a large range between high- and low-river levels, and contributes the bulk of both water and silt to the main Nile in flood.

The White Nile is navigable for over 1,000 miles, has a low undefined foreshore in most places, and large depressions occur along its banks which are inundated in the flood season. The flow is sluggish, and the range between high- and low-river levels is small. The water carries practically no silt, and the river contributes only about one-seventh of the total Nile volume during the flood period.

Rainfall and Vegetation

The rainfall increases rapidly from north to south throughout the province, and all isohyets swing sharply northwards between the White and Blue Niles. The northern Gezira, as far as Medani, carries little in the way of vegetation beyond a sparse growth of grass. From there, southwards, both grasses and trees increase steadily with the improved rainfall. From Sennar to Wad en-Nail the acacias predominate, and numerous forests of sunt (*Acacia arabica* Willd.) are found in the loops and basins fringing the river (Fig. 300). From Wad en-Nail southwards the improved rainfall and the rising slope of the land tend to give a gradual increase in broad-leaved trees, though the thorny acacias still form the bulk of the vegetation, especially in the clay plains. The rainfall generally extends over the period May to September, with the heaviest falls concentrated in the months of July and August.

Tribal Divisions

Several factors have contributed to the involved tribal intermingling

FIG. 298. Typical country between Singa and Roseires, southern Blue Nile (*photo F. Crowther*).

FIG. 299. Packing cotton in the field: Gezira Scheme (*photo F. Crowther*).

that is so typical of the province. The two Niles have provided natural highways for traffic, both by boat and for parties proceeding by land. Markets sprang up at various places along both rivers, and to these centres the peoples lying to both east and west drifted in the course of trade. The Gezira area was also formerly a main centre for grain production and for the slave-trade. The province lies on the main pilgrim route for those proceeding to Mecca from West Africa or vice versa. These pilgrims, consisting mainly of Nigerians, and Burno and Burgo from French Africa, earn money for their journey by working in the Gezira

FIG. 300. Sunt (*Acacia arabica* Willd.) forest flooded at high Nile near Singa (*photo F. Crowther*).

and form an important, though somewhat fluctuating, addition to its supply of labour. The Abyssinian frontier has also been a happy hunting-ground for armed poaching parties in the past, and their booty often included cattle and captured black ivory in addition to hunting trophies. As a result, clear-cut tribal divisions are few, and these are mainly confined to the pastoral tribes occupying the extreme eastern and western boundaries.

Arabic is generally spoken throughout the province except in the southern portion: here various languages are spoken which bear some affinities to those used by the Nilotic (White Nile) tribes. The main divisions of these are: (*a*) Ingessana, (*b*) Berta, including two groups of dialects, (*c*) Uduk, (*d*) Gule, and (*e*) Burun, comprising northern and southern dialect groups. At Maiurno and other places along the Blue Nile permanent settlements of Nigerians are found; these are generally bilingual, speaking both Arabic and their own languages. Some of the West Africans have also settled in the Gezira irrigated area and taken up holdings.

Agricultural and Grazing Areas

The main agricultural areas can best be grouped as follows:

(*a*) *Rain areas:*	(i) Light rainfall areas. (ii) Heavier rainfall areas.
(*b*) *River lands:* including reservoir areas	(i) Blue Nile. (ii) White Nile.
(*c*) *Irrigation:*	(i) Free flow—Gezira and Abd el Māgid area. (ii) Pumping Schemes: (*a*) Government; (*b*) private.

The above are dealt with more fully in the sections which follow.

The main grazing areas are those occupied by the Hassaniya, Baggara, Shukriya, and (to a lesser extent) by the Kawahla and Kenana administrations. These are also discussed more fully in the sections which follow immediately. Although the rainfall over most of the province is adequate to provide for good grazing for a large livestock population, the breeding of both cattle and sheep for the production of meat and hides has never assumed a large proportion of the general trade of the province. This is all the more surprising when the availability both of markets and of easy transport is taken into consideration.

THE GEZIRA SCHEME

Introduction

The Gezira Scheme is run on a unique system of triple partnership, based on a share-farming system. It is the main cotton-producing area in the Sudan and is irrigated by free flow from the Sennar Dam. The total gross area included in the scheme, in the 1942–3 season, was some 980,813 feddans.[1] Of this total 714,343 was native-owned, and the Government-owned land amounted to 248,221 feddans; a further 18,249 feddans was taken up by roads, villages, and village 'haram' (uncultivated land surrounding village sites).

For the same season the areas in feddans under crop or resting were:

Cotton	216,869	
Dura	114,238	
'Lubia'	40,101	
Wheat	17,919	(9,871 outside normal rotation)
Resting	494,403	(including 5,236 non rotation land)
	883,530	
Deduct	9,871	(wheat, on fringe areas)
Normal area	873,659	

The balance of some 107,000 feddans is taken up by canals, roads and watercourses, villages and precincts, &c.

[1] 1 feddan = 1·038 acres = 0·420 hectare.

The partners involved are the Sudan Government, two Companies (the Sudan Plantations Syndicate Ltd. and the Kassala Cotton Co. Ltd.), and the native tenants.

In return for a percentage share of the results each partner undertakes specific obligations and duties. Functions are allocated, and the benefits and risks of production are shared proportionately between the partners.

FIG. 301. Camels bringing raw cotton from the fields to a collecting station for transport by light railway to a ginnery. Gezira scene.

The obligations of the respective partners are:

Government: Provision of the land; construction, maintenance, and operation of the Sennar Dam, the Main Canal, and the main canalization; payment of rents for the land.

Concession Companies: The construction and maintenance of subsidiary canalization; the clearing and levelling of land; the provision and working of ginning factories; the provision and maintenance of buildings, machinery, stores, and supplies required to enable the companies to carry out their functions; generally to manage and supervise the letting of land, the cultivating by the tenants; the collecting, storing, and marketing of the cotton crop (including seed); the making of loans to tenants.

Tenant-Cultivators: The growing of crops under supervision of the Companies and the provision of the necessary labour.

The Government has taken a 40 years' lease from the registered owners of all the land within the scheme at a fixed annual rental of 10 P.T. per feddan. Land required for permanent works outside the scheme is purchased by the Government at £E.1 per feddan, but in some instances has been expropriated. These prices are based on the highest prices obtainable for land before the inception of the scheme. The present agreements with the Companies are terminable in 1950. The Companies own no land in the Gezira.

The irrigation aspects of the scheme are discussed in detail in the section commencing on p. 598.

1. *Land Settlement and Allocation*

Pre-irrigation Cultivation

To visualize the changes which have taken place in the Gezira irrigated area it is necessary to picture the original state of affairs there before canalization was introduced. The Gezira then consisted of a gently sloping, flat, clay plain on which cultivators grew a rain-grown dura crop. The rainfall in the north was uncertain, but, towards the south, gradually trended into a zone of 16–20 in. annually.

To make the fullest use of the rains (especially in areas of low rainfall) small earthen banks were constructed. These divided up the land into a complicated jig-saw pattern. Villages were dotted here and there, usually on high land useless for cultivation, and their inhabitants had to obtain their water by raising it laboriously from deep wells. During the rainy season cultivators often grew their crops far from these permanent villages, so many temporary dwellings were constructed. These were occupied for a few months only and were often supplied with a pond for storing rain-water. The production of dura was always uncertain: the rains might fail or tail off after a good start, pests or parasitic plants might ruin a good crop, and the lack of rotation steadily exhausted even the better areas. With the introduction of a scheme of planned canalization it became essential to survey the whole area and to ascertain the holdings of those who cultivated there.

Survey Work and Registration

An initial contour survey was started in 1904 by a Sudan branch of the Egyptian Irrigation Service. In 1906 a cadastral survey was also undertaken. The land was divided into minute squares and the corner of each square was marked by an iron beacon showing the degrees and minutes of latitude and longitude. Twenty-five squares (roughly 25 square miles) formed a registration unit or section. The first work was started in the Medani, Mesellemiya, and Kamlin sections, on the west bank of the Blue Nile. A land-settlement party worked along with the cadastral survey, in order to obtain a register of title to all lands held within the demarcated area. That this work was well and efficiently done is proved by the very small number of disputes in respect of registered land that have since been raised.

In order to lay out the scheme on efficient lines it was necessary to superimpose on the old boundaries a grid of canalization, including agricultural fields of uniform size. The Government therefore compulsorily rented the land from the registered holders for 40 years at a fixed annual rental of 10 P.T. per feddan. Land required for permanent works could be purchased outright, or expropriated, though this was not done in all cases.

Allocation to Owners of Land

Steps were also taken to prevent speculation in land and the alienation of rights by natives to foreigners or to native usurers. One of the first proclamations made by the Sudan Government (in 1900) forbade the sales of land, unless previously approved by the Governor of the province

concerned. Specific application of this general ruling to the Gezira area was further emphasized by a notice published in February 1914 which stated that the consent of the Governor would not be granted to 'any sales or dispositions by the natives of the Sudan of *lands in the Gezira* effected after 1st July 1905, except such sales *to other natives of the same locality as have hitherto been customary and may be deemed by the Governor to be proper*'. The procedure for the renting of land within the boundaries of the irrigated area is laid down in the Gezira Land Ordinance of 1927; this amended and repealed earlier legislation published in 1921 and 1923. By its provisions the rights of owners of land within the area are safeguarded, and three classes are accorded privileged treatment, namely, 'right-holders', 'nominees', and 'preferential tenants', as explained below. These groups are accorded first claim to tenancies within the irrigated zone. The standard size of plot adopted was 10 feddans, as it was considered that a tenant and his family could not competently cultivate more than 10 feddans of cotton. Original holdings, on a three-course rotation, were therefore 30 feddans, but this was later altered to 40 feddans when the basic rotation was changed. Allocations of tenancies, which did not necessarily coincide with the original holdings, were made as follows:

(i) *Right-holders*: those who owned 40 feddans or more had first claim. The right-holder could either cultivate himself or appoint nominees to farm his land. Right-holders normally cultivated only one holding, unless the Companies' representative agreed to more; an owner of 120 feddans could therefore take up one holding himself and nominate two others to cultivate the balance. Sons of right-holders were also included in this category.

(ii) *Nominees*: normally the pre-scheme cultivators or relatives of the class above. When there are several claimants to a 40-feddan holding they can select one of their number who then has the privileges of a right-holder. Tenancies *must* be allocated to right-holders and to legal nominees unless they have a bad cultivation record; in such cases they are persuaded to nominate someone else. In the case of nominees, other than heirs, the Companies are not compelled to accept those with bad records.

(iii) *Preferential tenants*: these are landowners who hold 20 feddans or more, but not enough to qualify as right-holders. They are allotted tenancies in preference to landless men. After these three classes have been satisfied further allocations are made to those considered suitable, usually after consultation with the native authorities concerned. The allotment of the holdings on the land is done by the Companies. Although the land is leased from owners these still retain freehold rights, and can bequeath their land according to Mohammedan law, subject to certain restrictions imposed to prevent cumbersome subdivisions. In practice it has been found that the farming of 10 feddans of cotton is rather beyond the powers of an average family, and reduced holdings have been introduced in some cases.

Sales of Land

Land sales are controlled by Ordinances dated 1918 and 1922 and by rules issued by the Governor.

Canal. Incidentally the large pumps at Hag 'Abdullah and Wad en Nau still operate during the 'dead season', as they supply domestic water to the whole of the present canalized area of some 870,000 feddans during May, June, and part of July. From 1925 to 1926 water from the Main canal became available, and since then expansion has proceeded steadily, as indicated by the appendix showing areas and yields in the Gezira.

Government Administration

The area covered by the concession forms a part of the Blue Nile Province which has its administrative headquarters at Wad Medani. In the earlier stages of development special 'Gezira Commissioners' were appointed to act as liaison officers between the Companies and the local authorities and cultivating tenants. They also performed specific functions during the allotment of tenancies as and when expansions to the irrigated area were carried out.

When conditions became more stable the Gezira Commissioner became the staff officer to the Governor and adviser on problems connected with the cotton Companies, but on the outbreak of war in 1939 this post was held in abeyance. Points of policy are now dealt with directly between the Governor of the province and the Companies' Manager, while matters of everyday routine are conducted through the District Commissioners of the two districts in which the concession area lies.

A Senior Agricultural Inspector, stationed in Wad Medani, maintains close touch with the Governor in respect of the various agricultural activities and problems affecting the province.

The Irrigation Department's headquarters are also sited at Medani. The control of the supply of water and general maintenance are more fully described in the chapter on 'Irrigation'.

The medical authorities are also very actively interested in the health and welfare of the scheme as a whole. Large hospitals exist at Sennar, Wad Medani, and Abu Ushar, and dispensaries are scattered throughout the whole irrigated area. Public Health Inspectors, controlling a staff of mosquito-men, are also based at various centres; outbreaks of malaria are reported, and control of these ensured by the baling out or oiling of pools at infection centres (Fig. 309).

Responsibility for the maintenance of public security in the irrigated area is vested in a force of state police under a Commandant who is himself responsible to the Governor of the province.

The Companies' Administration

The Companies comprise the Sudan Plantations Syndicate Ltd. and the Kassala Cotton Company Ltd., both under joint direction. The local managing headquarters of the Syndicate and Kassala Cotton Company are situated at Barakat and Wad Shair respectively. The Syndicate area is divided into 33 blocks, each in charge of a 'Block Inspector' with a varying number of junior inspectors under him. The size of blocks varies, and the smaller blocks (under 3,500 feddans of cotton) are often run by the Block Inspector alone. Houses are situated for the staff throughout the whole area but, with the greatly reduced staff operating as a result of

FIG. 302. Cotton arriving by camel at Hag 'Abdallah Station (*photo F. Crowther*).

FIG. 303. Ginning factory: Meringān (*photo A. R. Lambert*).

the war, many of them are now unoccupied. Four groups, each consisting of a varying number of blocks, are controlled by 'Group Inspectors' each of whom lives in a central house in his group. The Kassala Cotton Company's blocks form a group of their own; the name of the Company commemorates the fact that they surrendered their concession in the Gash Delta in 1927 and transferred their activities to the Gezira. The gross area of this Company has gradually grown to its present size. The control of mechanical plant, workshops, &c., is centred at Marangān, lying between Barakat and Medani. Groups of ginning factories, each in charge

FIG. 304. Camels have brought raw cotton to a railway station from where it will go by rail to a ginnery. A Gezira scene.

of an inspector, exist at Marangān and Qurashi. A small ginning factory at Wad Medani, constructed in the early days of the scheme, has not operated for many years, but could do so in an emergency. The authority of inspectors does not extend beyond the agricultural supervision of the tenants, and they have no punitive or legal powers, these being vested in the Administration officials and native authorities.

Local Government Administration

There has been a steady expansion in the use of, and the powers granted to, native authorities during the past few years. These now deal with many cases which were formerly referred to District Commissioners. In addition to the wider administrative, financial, and judicial powers allocated to Nazirs and Omdas, four lesser authorities have had certain powers delegated to them in various parts of the Gezira Scheme. These are the Block Councils, Village Councils, Agricultural Sheikhs (also known as 'wakil sheikhs' and 'samad'), and 'War-time Samad'.

Devolution was started first and has proceeded farthest in Hosh block, where the first three have been operating since 1940. Village councils exist in various blocks, and agricultural sheikhs are also being tried out on a fairly wide scale.

The Block Council is composed of members of the various Village

Councils; its duties are mainly advisory, but it also forms a court of appeal against decisions given by Village Councils. Village Councils exist in Hosh, Fahl, Remeitab, Wad el Atai, Medina, Taiyiba, Nidiana, Dolga, Istrahna, Wad Hussein, Um Degarsi, Kab el Gidad, and Turis blocks. The council ('meglis') controls the actions of the 'samad' and supports his authority, prevents him from becoming too bureaucratic, and encourages the community spirit amongst all those concerned. The village sheikh is President, and its members are selected by vote from amongst the tenants

FIG. 305. Ginnery at Meringān of the Sudan Plantations Syndicate. Seed-cotton is stacked in the background ready for ginning whilst the bales of lint in the foreground await transport to Port Sudan.

farming the land in the vicinity of the village or others, e.g. Government officials. Penalties can be imposed for the misuse of irrigation water, damage by animals, &c.

The 'samad' may also be sheikhs, but are more usually not. They are the executive agents of their village and they supervise cotton areas of 140 to 700 feddans (average about 400 feddans). They have to organize the agricultural activities of their village, to act as the village representatives in dealings with the British Inspector, and to pass on his instructions and advice. They are encouraged not to act as mere agents, but to use their initiative and improve the interests and welfare of those under their charge. In some instances they have undertaken the assessment and submission of the weekly 'indent' for water required, and the supervision of its use for irrigation. They draw a monthly salary, paid by the Government, and a bonus for each kantar of cotton picked; the latter charge is shared by all three partners.

The 'war-time samad' is rather different, as he is appointed by the Companies to help out the war-time shortage of British staff. He is paid

by the Companies as their agricultural agent, and his bonus on cotton pickings is borne between Government and Companies only. The use of war-time samad has spread to many areas, and they have proved their value, though they have not the executive powers of the other authorities. Though they are of varying efficiency, they will be absorbed, if suitable, into the Village Council system as it extends.

The boundaries between the various administrative units in the irrigated area have recently been realined so that they now coincide throughout with the agricultural (i.e. block) boundaries, which are themselves dependent on the irrigation layout.

3. *Crop Rotations*

The original Taiyiba and Barakat schemes were definitely experimental and various crops were tried out, with cotton as the principal one. Taiyiba was mainly on a three-course cotton–'lubia'–resting, and Barakat on a cotton–resting–resting–rotation; other crops, such as wheat and dura, were also grown. Hosh and Wad en Nau introduced the three-course (actually six-course) rotation which, from 1921 to 1929, was used throughout the Gezira. This rotation was: cotton 10 feddans; 'lubia' 5; dura 5; resting 10. The position of the dura and 'lubia' plots was reversed in the following cycle. During the period 1929–31 the size of the 'lubia' holding was increased slightly, at the expense of dura. The 1929–30 and 1930–1 seasons gave such poor cotton yields that a revised rotation was considered essential. An interim rotation of cotton–resting–resting was introduced for two seasons. Dura was essential as a food crop, and so was grown on separate areas, outside the cotton rotation. This makeshift arrangement, which was never popular, was replaced from 1933 to 1934 onwards by the present eight-course rotation. Holdings were increased to 40 feddans, and the cropping adopted is: cotton–resting–resting–cotton–resting–dura–'lubia' or resting–resting.

Briefly the points to note are:

(i) Cotton is preceded by two periods of rest (except where 'lubia' is grown) and followed by at least one year of rest.

(ii) Dura is preceded by a rest and the holding is shared by two adjoining tenants.

(iii) 'Lubia' holdings, when sown, are also shared as in the case of dura.

(iv) The large percentage of uncropped or resting land to crop: this rotation therefore requires more canalization per unit of productive crop than is found in most irrigated schemes.

Although the present rotation is somewhat wasteful with regard to the use of land, its effects have been good on the yields obtained, both from cotton and the other crops sown. It is therefore likely to continue in force, as it suits the conditions of to-day admirably. If conditions altered, especially on account of population pressure, it would not be too hard to change.

Departures from the General Rotation

Several blocks or areas, which are irrigated from the main canal, show a divergence from the general rotation noted above.

These are:

(i) The Qundal Scheme
(ii) The Abd el Māgid Scheme } Government schemes.
(iii) The Gezira Research Farm
(iv) Fawar block in the Kassala Cotton Company concession area.
(v) Suleimi block
(vi) Abd el Hakim block } in the Sudan Plantations Syndicate area.
(vii) The Barakat Seed Farm

The first three are discussed more fully elsewhere, as they do not form part of the 'Gezira Scheme' proper; the seed farm is an experimental area and, though it conforms in general to the main rotation, various trials may be carried out from time to time with new varieties, application of manures, or the trying out of modified cultural or irrigation methods, &c. All cotton grown there is ginned separately in the seed farm ginnery, in order to prevent mixing of seed, and the tenants cultivating are compensated whenever the effects of experimental work carried out causes a depression of yields below the average figure. The other three blocks are discussed below.

Abd el Hakim

When the present rotation was introduced into the Gezira in 1933–4, certain blocks were cropped on modified three- or four-course rotations in order to get comparable results. At Abd el Hakim two rotations were tried out, a three-course and a four-course.

The three-course was, from 1933 to 1937 inclusive:[1]

C 8 L 2 ⟶ D 5–R 5 ⟶ R 10. Total 30 feddans.

From 1937–8 to the present this has been changed to:

C 8 L 2 ⟶ R 5–D 5 ⟶ R 10. Total 30 feddans.

The dura plot and the position of the 'lubia' strip now alternate, so the rotation is really a six-course one. The three-course rotation has now been abandoned at the request of the tenants concerned.

The four-course rotation was also modified after being tried out for 4 years (1933–7); originally it was similar to the first trial rotation above, but with an extra resting period introduced, viz.:

C 8–L2 ⟶ D 5–R5 ⟶ R 10 ⟶ R 10. Total 40 feddans.

In 1937 this was changed to:

C 10 ⟶ R 10 ⟶ L 5–D 5 ⟶ D 5–L 5 ⟶
R 10 ⟶ C 10 ⟶ R 10 ⟶ R 10.

This latter rotation is thus really an eight-course one, operating on a 40-feddan holding.

A reference to the diagram at p. 777 will clarify the rotations used, both past and present.

[1] C = cotton; D = dura; L = 'lubia'; R = resting, uncultivated land, Arabic 'bor'.

Suleimi Block

In 1938–9 it was decided to crop over 2,000 feddans gross of the Suleimi block on the 'Old Gezira rotation', so as to obtain a direct comparison with the present main rotation. This experiment has therefore continued for a few seasons only, but results indicate that the more intensive use of the land obtained from the old rotation is offset by various disadvantages such as weediness, lower yields, &c.

Fawar Block

The Fawar block, in the Kassala Cotton Company area, was the first area in the Gezira proper to show a complete break from the old methods of cropping, size of holdings, and administrative methods.

The size of the 'howāsha' was reduced from 10 to 8 feddans; the rotation adopted included 'lubia' in the annual cropping, so as to allow for mixed farming methods; the villages were grouped in a central position and were laid out on model lines; fuel plots were introduced in order to provide for firewood requirements; increased use was made of bull-ploughing and also of native authorities for supervision and control. The Fawar scheme was started in 1936–7, on a gross area of 4,752 feddans and subsequently extended; the effects of the various modifications is discussed briefly below.

Rotation. The size of 'howāsha' was reduced to 8 feddans and the tenancy to 24 feddans in all. The cropped areas have proved to be more within the capacity of the family unit, and less hired labour has to be employed at peak periods.

The first rotation adopted was the 'screening rotation', also adopted at Qundal. This was:

$$\text{C 6–D 2} \longrightarrow \text{D 2–L 2–R 4} \longrightarrow \text{R 8. Total 24 feddans.}$$

The object of the dura strips was to form a screen and so reduce the chances of blackarm infection carried over from the cotton area of the previous season. It is obvious that the rotation is rather an exhausting one and that the cotton plot has three rotation pedigrees.

The screens did not prevent blackarm infections, and so the rotation has been changed (from 1940 to 1941 onwards) to a variant of the 'old Gezira rotation', viz.:

$$\text{C 8} \longrightarrow \text{D 4–L 4} \longrightarrow \text{R 8. Total 24 feddans.}$$

Actually 2 feddans of the 'lubia' area was made compulsory, and the sowing of the other 2 feddans was optional. From the same season optional vegetable plots of 4 feddans were also allowed. These, where introduced, were sited near the villages, and the resting areas near villages reduced by a corresponding amount to allow for the slight readjustment of tenancies thereby required.

Mixed Farming. This is mainly discussed in the preceding section. For bull-ploughing, one pair was originally allowed per nine tenancies, the animals being distributed amongst sheikhs and selected tenants. Mortality amongst the original livestock was heavy until 'compulsory stacking' was adopted; by this system each tenant had to make four stacks

financed by advances; of these the heaviest expenditure of both money and labour is incurred on hoeing to clear off the weed-growth, often very heavy in years of abundant rains.

In the majority of years, on account of rainfall, irrigation is only needed on a modest scale until about mid-September. At this season decision as to when the watering of the young plants should be done requires much judgement, for, if watering is followed by heavy rains, waterlogging and damage to the seedlings may easily result (Fig. 307).

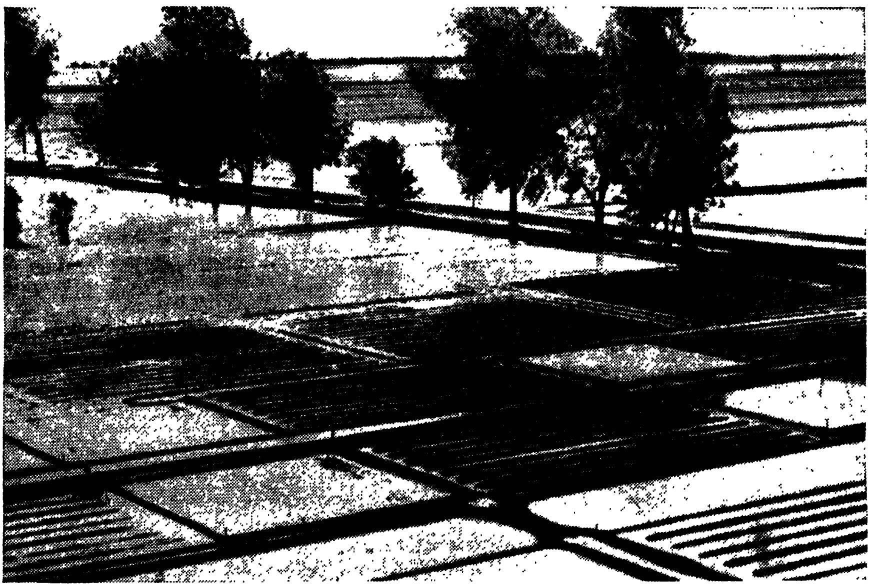


FIG. 307. Rains are a mixed blessing on irrigated land. This was an unwanted flood after heavy rain at the Gezira Research Farm (*photo M. C. Hattersley*).

Early waterings are usually given at 10–12-day intervals, extending to 14–15-day intervals as the crop increases in size and the weather becomes cooler. From October to December little can be done to the growing cotton beyond giving it regular waterings. Flowering is general in November and picking starts about the beginning of January. It should be noted that Sakel cotton starts to mature rather earlier, and finishes its picking quicker, than the L cottons (X1730 and kindred types). Picking is continuous throughout the period of January to April, the fields being picked as clear as possible between watering periods. Fields consist of 16 'angaia', and during the picking season waterings are given at 16-day intervals as this period fits in best with the layout and the distribution of labour. Sacks are issued to the cultivators and payments are made for each kantar of cotton, delivered either at the ginneries or at the collecting stations on the Gezira light railway or on the Sudan railways. Watering is usually discontinued at the end of March, but picking may continue for another month. The cultivator has then to extract his cotton by the roots, using the special cotton puller, collect and burn the stalks, and clean up

FIG. 308. Young cotton ridged up (right), unridged and unweeded (left) (*photo F. Crowther*)

FIG. 109. Watercourse (abu sitta) irrigating cotton: inspection for mosquito larvae (*photo T. J. Lewis*).

the old cotton area as much as possible from debris, &c., by the end of May. The end of the season is usually heralded by the arrival of swarms of goats, sheep, and cattle belonging to nomad tribes who seize this chance to obtain green forage for their animals at a time when grazing is scarce, and they also help with clearing the old crop from the fields.

(ii) *Dura.* This is the main food crop and is normally grown 'on the flat' with only light banks to control the spread of irrigation water. Various types of grain are sown; the most popular are probably Feterita, Hemeisi, and Qassābi. The crop is sown in July, without pre-watering if the rains are favourable, but the full area of approximately 100,000 feddans may not be completed till well into August. The waterings given rather depend on subsequent rainfall, the general average being 3–4: irrigation of the crop ceases at the end of October, and threshings are carried out during November and December, i.e. before cotton picking starts.

The early Feterita duras require only 85–90 days to mature, and most of the duras sown have a quick or medium maturing period.

No charges are made to cultivators for water-supplies, and the grain and stalks ('qassab') are theirs to dispose of as they wish, provided the stalks are not removed from the land as this would cause a reduction of its fertility. The 'qassab' is used both for fodder and for the construction of shelters.

(iii) *Lubia.* 'Lubia' (*Dolichos lablab* Linn.) is the main fodder crop and provides valuable feeding for working bulls and other livestock. It is sown about mid-September and takes about 4½ months to mature. Though chiefly used as green fodder, seed is collected from parts of the gross area for next season's sowing and it may also be used as a food pulse. Originally 'lubia' was sown earlier, but the present date adopted gives good yields, eases the demand for water somewhat, and also reduces possible damage by a bacterial disease which affects earlier sown 'lubia'. About seven waterings are required, and irrigation is normally discontinued at the end of December. It will be realized that October is the month when the water demands of growing crops reach a maximum, as cotton, dura, and *Dolichos* all demand their share. The latter is either grazed *in situ* or is stacked for use during the lean months. As with dura, the 'lubia' crop is at the tenant's disposal, free of all charges.

(iv) *Wheat.* In order to reduce imports of wheat flour, and thereby to save shipping space, wheat was grown on a fairly large scale in the Gezira during the second world war. Land outside the normal rotation area was employed for the growing of this crop, and good yields were obtained. The crop is sown in November and harvested in March. As wheat forms no part of the normal rotation, further comment is unnecessary.

(v) *Preparation of Land.* The land intended for cotton is the only part of the scheme which receives cultivation well in advance of sowing. As soon as conditions allow after the rains, usually about October, the Diesel ploughing sets are sent out to plough the next season's fields. These units consist of two engines, operating a cable-drawn cultivator and set of ridging ploughs. Formerly, cultivating and ridging were carried out independently, two operations being required. Now both are done at once wherever possible, thus reducing costs and speeding up the work. One ploughing set is capable of cultivating and ridging up some 40 feddans

The general basis for 'sāqiya' cultivation is that half the crop goes towards labour and half towards maintaining the water-wheel and the animals which raise the water to the land. In the Gezira the Government meets the costs of land-rent and the cultivators are supplied with a holding and the necessary irrigation water. They also get their food- and forage-crops free of all charges and are thus much better off than a 'sāqiya' cultivator working under native conditions.

It will be readily realized that accounting for a crop which includes not only the current season's cotton production but also unsold amounts carried forward from previous years is a very involved business.

The tenants' shares of the profits are passed to a 'Tenants' Collective Account' from which payments are made as sales proceed. Each season a 'proforma price' is worked out per kantar, for each grade of cotton produced, and initial credits are made to tenants on this basis. Later payments, known as 'appreciations', are made according to prices received for the cotton: these, for simplification, are calculated on a flat rate per kantar, and an endeavour is made to issue them at times when the tenants' need for ready cash is most acute, and when the money will have the least inflationary effect on labour rates.

The lag in closing accounts for any particular season is unsatisfactory for many reasons, and various methods for improvement have been proposed. One of these is to complete sales in the Sudan and, in the years preceding the war, the Companies sold considerable amounts of their cotton (chiefly of the 'L' types) through a sales office opened by them at Port Sudan.

Reserve and Equalization Funds

During the 1929–30 and 1930–1 seasons the Gezira went through a very critical period. Low cotton yields coincided with world-wide depression and reduced prices for all commodities. Even with restricted advances to tenants, many of these were unable to meet their commitments and there were many 'bad debts' carried forward, amounting to some £E.600,000, which were jointly borne by advances made by both the Government and the Companies. After a few seasons of partial recovery the position has improved greatly. To prevent the recurrence of a similar state of affairs funds have been gradually built up to serve as a general reserve and to equalize seasons of low cotton prices. Contributions have been made to these funds by both the Companies and the Government either directly or indirectly by waiving their claims to amounts previously advanced. Contributions have been obtained from the tenants' accounts by levies, and these, incidentally, have been of value in reducing any tendency towards war-time inflation by removing surplus money from circulation. The various funds created have now been amalgamated into one general 'Tenants' Reserve Fund' which can be utilized to counter any recurrence of low yields or of low prices.

6. *The Gezira: Past and Future Development*

The Past History

It is most convenient to trace the agricultural history of the Gezira from 1925 to 1926, when free-flow irrigation first became available. The original

TABLE SHOWING AREAS AND YIELDS OF COTTON IN THE GEZIRA

Kantars of 315 rotls seed-cotton

GEZIRA

Year	*Feddans*	*Kantars*	*Average yield per feddan*
1912	250	1,330	5·32
1913	610	3,062	5·02
1914	668	2,538	3·80
1915	2,963	15,674	5·29
1916	3,361	11,159	3·32
1917	4,301	14,236	3·31
1918	3,855	12,683	3·29
1919	3,964	13,200	3·33
1920	3,756	19,557	5·26
1921	3,711	12,135	3·27
1922	9,818	38,487	3·92
1923	10,386	38,013	3·66
1924	22,496	64,339	2·86
1925	21,616	47,771	2·21
1926	80,301	384,642	4·79
1927	100,057	477,272	4 77
1928	105,587	347,973	3·29
1929	131,351	466,168	3·54
1930	174,183	405,670	2·33
1931	196,023	266,343	1·36
1932	193,979	805,051	4·15
1933	194,975	375,476	1 92
1934	174,912	409,960	2·34
1935	175,183	781,555	4·46
1936	184,740	687,660	3 72
1937	199,125	890,907	4·47
1938	208,373	957,394	4·59
1939	210,226	936,829	4·45
1940	211,259	810,097	3·83
1941	214,463	887,577	4·13
1942	216,951	873,081	4·02
1943	216,688	1,043,285	4·81
1944	216,894	668,552	3·08
1945	216,863	1,066,148	4·92
1946	196,541	660,844	3·36

first target was then 300,000 feddans, with 100,000 feddans of cotton. In the first year only 80,000 feddans of cotton were grown, but the full area was attained the following season. The average yields obtained were high, and prices were satisfactory; the pious hope was expressed that cotton would not fall below 14½*d.* per lb. as 'present prices are, of course, very much higher than this'. An average yield of 3 kantars per feddan was also considered very safe. For the next few years, additions were made annually to the scheme.

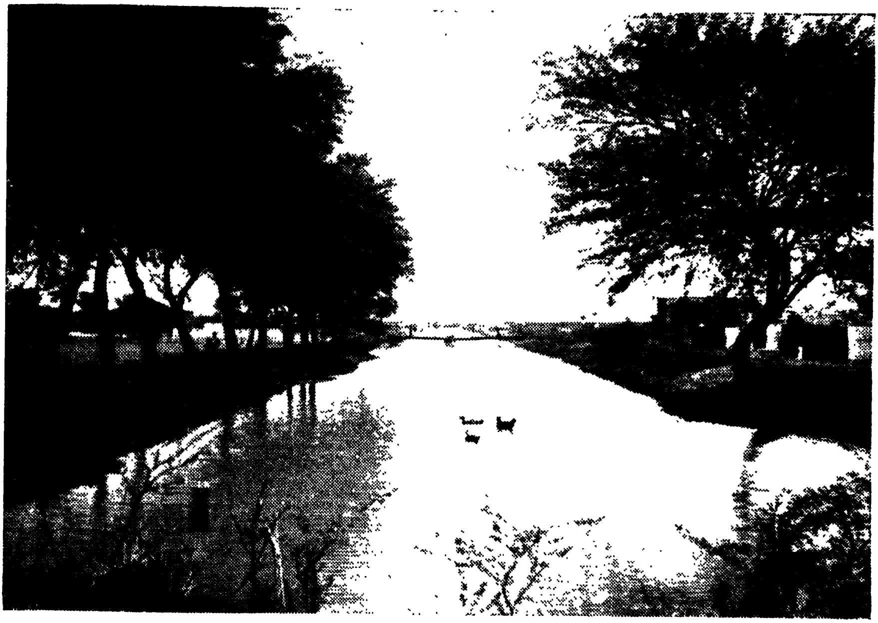


FIG. 310. The clay of the Gezira, unlike that of the Dueim area, is remarkably even in quality. Barakat III minor canal (*photo F. Crowther*).

In 1929–30 a large expansion was made, which included the first three blocks of the Kassala Cotton Company's concession in the Gezira. This season was one of considerable anxiety. The average yield was low, mainly owing to heavy blackarm and leaf curl damage, and Sakel cotton prices slumped to about 8*d.* per lb., owing to world-wide depression. The crisis was intensified in 1930–1 when the Gezira average yield was only 1·36 kantars per feddan and the average Sakel price declined to under 7*d.* per lb. Urgent measures were put in hand in order to counter these depressed yields.

Leaf curl was largely eliminated by pulling out the cotton plants by the roots, instead of cutting them at ground level. The old method did not obviate ratoons, which formed the most serious source of leaf curl infection. The cotton seed was mainly imported from Egypt and was treated with 'Abavit B', a mercurial seed-dressing, in order to decrease the incidence of blackarm. At the same time an interim rotation was adopted until a satisfactory four-course rotation could be evolved.

In 1931–2 good yields were obtained, but the following season again showed a low average figure. Increasing areas of X1530A and X1730A

cotton (generally referred to as 'L' type cottons) were then introduced. These types were originally selected by A. R. Lambert from Sakel, but they show marked differences both in their vegetative growth and in lint produced. Their outstanding characteristics are: high yields, high ginning out-turn, marked resistance to leaf curl, and great powers of recovery from severe blackarm attack. The danger from leaf curl was largely checked by cotton pulling, the growing of resistant types, and the wide rotation adopted. The area sown with 'L' cottons increased steadily and now forms some 50–60 per cent. of the total. Treatment of the seed with 'Abavit B', as a check against blackarm, has been continued as a routine and the sowing date has been retarded somewhat, as it was found that primary infection by this disease decreased rapidly after 15 August. The adoption of the eight-course rotation has also benefited both the cotton and the dura crops, and average yields during the last few seasons have been very satisfactory.

The war has inevitably caused changes in the normal routine. The Companies have released a large proportion of their staff, thereby throwing a greater burden on those who remained and also on the various branches of native administration; labour has fluctuated and has often been scanty; additional crops, both of dura and of wheat, have been sown to augment food-supplies; shortages of material and of transport have added greatly to the difficulties of harvesting the various crops. On the other hand, the cotton crop has been disposed of promptly at satisfactory prices, and there has been little or no delay resulting from unsold stocks of cotton or the closure of accounts. Everyone has worked hard to produce the maximum required by war-time needs, and although cotton prices have been strictly controlled, the tenants are more prosperous than they have been for many years.

The Future

The policy of the Government with regard to the future of the Gezira may be summed up as follows:

General. To train up a class of small farmers who, when the concession period is ended, can make the best use of the permanent irrigation system established in the Gezira.

Land. To control sale of land by natives so that it will pass into the hands of:

(*a*) The Government as trustee for the people of the Sudan, or
(*b*) only such persons as can eventually form part of the class of small farmers referred to above.

The land purchased by the Government will finally be available for sale or lease to such potential farmers, either as individuals or as village communities, who have not been able to obtain land themselves.

Administration.

(*a*) To develop an orderly organization of village communities controlled by headmen selected by themselves.
(*b*) To devolve civic and agricultural control of the farmers to agents of this organization (e.g. agricultural sheikhs) and the use of village

and other councils and of native courts to support and enforce the authority of these agents.

Agricultural. To produce a class of mixed farmers with a permanent stake in the land which they farm. To this end (*a*) the cultivation of food, and possibly of fodder crops, to be given as much importance as a money crop; (*b*) provision to be made for the agricultural education of native agents and selected farmers.

These objectives will take time to attain, as the average tenant displays little inclination to use his own initiative. He is content to draw his cash advances for cultivation instead of attempting to finance himself; he is still too inclined to employ hired labour rather than 'swinken with his hondes and laboure'; although he knows by heart the routine required for sowing, weeding, and irrigating the crops involved, he usually waits until direct orders are issued before commencing any of these operations. As with most Sudanese, he makes little attempt to lay by funds for a rainy day, or to improve the standards of his housing, diet, or living in general.

At the same time the Gezira has, to date, produced some very interesting results.

It is a unique example of a public utility undertaking in which the State, the People, and a form of Specialized Management work together in a co-partnership basis. The rewards for capital involved are based on the results obtained and not on a fixed charge; this has resulted in careful supervision and management effort by all concerned. By renting the land the Government has safeguarded the interests of freeholders and has been enabled to lay out the scheme to the best advantage without being fettered by restrictions and petty difficulties. The tenants in the scheme enjoy the benefits of co-operative farming in many ways. Their food crop is assured and no rents are paid by them for land or water; their ploughing is done for them, and advances are given during the cultivation season to finance the most costly operations; they benefit from expert advice and management, and their crops are protected from diseases and pests by constant scientific research; their general health is ensured by the provision of free medical facilities throughout the scheme.

Although many of these advantages are of a co-operative nature, the individual reaps the reward of his own effort, and his returns are directly proportional to the energy and initiative expended by him during the season.

Jebel Aulia Compensation and the Alternative Livelihood Schemes

1. *Jebel Aulia Reservoir*

During the years 1933 to 1937 the Egyptian Government carried out the construction of the Jebel Aulia Dam, on the White Nile 27 miles above Khartoum. This was designed to store water to the level 377·20 metres, about 6 metres above the natural river at low stage. The slope of the White Nile is very small, and the filling of the reservoir affects the river to beyond Jebelein, about 200 miles upstream. The total contents are approximately 3,500 million cubic metres.

Under natural conditions the river was at its lowest stage about the end of April. Its level rose slowly until July, then slightly faster, to a maximum

which was normally in September, and from 3 to 4 metres above low-river. Thereafter it fell slowly but steadily to the low stage again. The river channel is wide, with gentle side slopes, and these included much fairly good soil, uncovered by the falling river in October and November.

The annual régime has been greatly changed by the construction of the reservoir. Since the waters of the White Nile contain practically no silt, the reservoir is filled as the flood rises, in July, August, and September. The full storage level is held steadily until early February, after which the contents are gradually released until the emptying is completed towards the end of April.

This change affected the livelihood of a large number of people living along both sides of the White Nile. Before the dam was built the economy of the inhabitants was based on a combination of cattle, rain cultivation, and riverain crops grown on the lands uncovered by the falling flood. On the breaking of the rains the people moved inland and occupied semi-permanent villages near their areas of rain cultivation. Here they raised their dura crops and grazed their cattle, and then moved back to the river about October, after the rain crops had been harvested. On the river slopes they were able to sow a crop of 'safra' dura, and the areas which were too heavily grassed for satisfactory cultivation provided good grazing for their animals.

The changes arising from the filling of the reservoir cut right across this mode of life. Although the areas inundated were much in excess of those previously watered by natural flooding, they were not uncovered until the season of hot weather was approaching. As a result growing conditions were unfavourable, and, in addition, on the lower levels the limited period available before the rise of the next flood was insufficient to allow many of the normal types of crop to mature. It may eventually prove possible to grow considerable amounts of food crops, but at present the production of forage seems to hold out the best prospects of success, and such crops will be grown at a season when fodder shortage is usually acute.

2. *Jebel Aulia Compensation—General*

Before the construction of the Jebel Aulia Dam was begun, an agreement was reached between Egypt and the Sudan for the payment in 1933 of the sum of £E.750,000, to be used to make good the loss and damage of all kinds which would result from the filling of the reservoir. To administer this fund, and to deal with all compensation problems, the Sudan Government set up in 1935 a Committee known as the 'Jebel Aulia Compensation Committee', under the chairmanship of the Governor of the Blue Nile Province. This committee was reconstituted in 1937 under the chairmanship of the Financial Secretary. Its members comprise the Governor of the Blue Nile Province and the Directors of Agriculture and Irrigation.

The measures found necessary to restore the situation may be summarized under the following heads:

(i) Protection (by means of banks) of towns and certain low-lying areas of cultivable lands, mostly used for rain cultivation.
(ii) Sanitation—chiefly to deal with the increased menace of malarial mosquitoes breeding on the fringes of the reservoir.
(iii) Compensation, chiefly in cash, for individual damage to lands, houses, and other interests.

(iv) Schemes of development to provide alternative means of livelihood for the riverain people.
(v) Sundry minor works, such as ferries, &c.

It was realized that while cash compensation would have to be paid to owners of lands which would be flooded at full reservoir level, this money would soon be spent, and it was most important to provide new means of livelihood for the population affected, and to ensure a production of food crops at least equal to that previously produced on the inundated lands. Though these totalled in all some 400,000 feddans, and though the population affected was estimated at about 200,000, the production of food crops over a number of years had averaged only about 60,000 to 70,000 ardebs of dura (of 336 rotls each). The reasons for this were that dura was usually sown only on the higher lands, that is, those uncovered by 15 October at latest; that of these only a part was of good quality, and much was badly infested with grass; and that of the crops sown, a good deal never matured as the result of damage by insect pests.

The assessment of claims for damage to property, &c., has proceeded steadily since 1935 and, to date, over 300,000 claims have been considered. Maximum compensation rates were fixed as follows:

Effective 'safra' land . .	P.T. 100 per feddan
Minor crop land . . .	" 60 "
'Fasda' (inferior) land . .	" 15 "
'Sāqiya' land	" 150 "

Land, other than river land, was estimated at its value as at 1 January 1934. It should be noted that the valuations of river land are for damage due to flooding only. Should the land prove to have no residual value, as a result of inundation, the question of full compensation will arise.

A new transhipment station has been built at Kosti and much of the town transferred to higher land. El Geteina and some forty-five villages have been resited entirely. Banks have been constructed at Sufi, Turaa, Shabasha, Salati, Ed Dueim, and elsewhere.

3. *Alternative Livelihood Schemes*

To provide new means of living, and the greater part of the food production needed, schemes of systematic irrigation have been developed under the control of a special Board, 'The White Nile Alternative Livelihood Board of Management', consisting of the Governor of the Blue Nile Province as chairman, and the Directors of Agriculture and Irrigation as members. Up to season 1943–4 inclusive, the following schemes had been brought into operation:

Scheme	*Approximate gross area (feddans)*	*Remarks*
Abd el Māgid .	38,500	*Forms part of the Gezira Canalization Scheme.*
Fatisa . . .	5,500	Pump Schemes on the White Nile.
Hashāba . .	7,300	
Umm Gerr . .	7,700	
Wad Nimr . .	1,200	

These schemes are described in more detail in the paragraphs which follow. The existing Government pump-scheme at Dueim, of some 1,700 feddans, will before long also be converted into an Alternative Livelihood Scheme, and probably extended by a further 1,000 feddans.

4. *Other Developments*

Development of private pump-schemes has helped in some measure to provide alternative means of livelihood, mainly in the southern part of the reservoir, though there the need for it is not so acute. The area so developed between 1934 and 1943 is 33,650 feddans. These schemes are discussed more fully in paragraph 8 below. Low-lift irrigation by 'sāqiya' and 'shadūf' on the reservoir fringes, or from short canals led inland, has begun on a small scale, and can be further developed, from the full reservoir level or within 50 cm. of it; this allows watering for about 5 months, from mid-September to mid-February. At one time it was hoped to find very considerable areas suitable for this method, but as the result of surveys of soil quality and land levels, it is now thought unlikely that the ultimate total available will much exceed about 5,000 feddans. Some areas of Government-owned rain-lands have been allotted to former riverain cultivators, in lieu of cash compensation, usually at the rate of 2 feddans rain-land for each feddan of river-land, but rain cultivation, in this area, is so uncertain that this is hardly an adequate alternative means of livelihood by itself, and is more of a palliative only.

5. *Transition Period*

The dam was completed, and storage of water begun, in 1937. But in order to give time for the readjustment of the population to new ways of life, and for the development of the various schemes, it was arranged that the reservoir should be brought into full operation gradually over a period of 6 years, in each of which the storage level was slightly higher than that of the previous year. Further, artificial flooding of the river lands was given in September, by raising the level for about 15 days to a higher 'topping' level, and then lowering it to the storage level, as follows:

Year	*Topping level (m.)*	*Storage level (m.)*	*Approx. gross area flooded (feddans)*	*Area of dura grown (feddans)*
1937	375·50	374·50	80,000	46,000
1938	376·00	375·10	94,000	51,000
1939	376·50	375·70	105,000	50,000
1940	376·90	376·20	109,000	38,000
1941	377·10	376·50	86,000	30,000
1942	377·20	376·80	58,000	19,000
1943	Normal filling to 377·20			

Of the land flooded, a good deal was only of mediocre quality, and other areas were unsuitable on account of grass or bush. Also, inevitable variations in reservoir levels, which occurred after the storage levels had been reached, re-flooded parts of these areas which thus could not be cultivated. Nevertheless, the figures given above show how by this means the food

resources of the district were materially increased. To some extent the success of the manipulation created a fresh problem, as in these years the people came to rely on a source of supply which was really only a temporary palliative.

6. *The Abd el Māgid Scheme*

Historical. This is the largest of the Alternative Livelihood Schemes and was the first to be constructed. The capital costs required for development, namely, £E.175,360, were originally provided from the compensation fund, but these have subsequently been recovered from the Government's central accounts.

An extension of the Gezira canal system provides the water for irrigation: various modifications have been made to the lay-out of canalization and the watering methods adopted which are discussed in the chapter on 'Irrigation'. The land required for development was expropriated at the flat rate of £E.1.000 m/m.s per feddan, and the expansion of the scheme to its present size is shown below:

Season	*Approx. gross area (feddans)*	*Dura crop* *Feddans*	*Dura crop* *Yield (ardebs)*	*Cotton crop* *Feddans*	*Cotton crop* *Yield (kantars)*	*'Lubia' crop (feddans)*	*Tenancies (No.)*	*Remarks*
1937–8	6,400	1,720	11,000	1,720	10,418	688	344	..
1938–9	16,600	4,515	30,000	4,515	20,784	1,806	903	..
1939–40	26,700	7,045 2,994	48,000 14,000	4,550	14,680	2,319	1,367	(Early sown dura) (Late sown dura)
1940–1	35,000	9,713	60,600	7,055	34,598	3,398	1,891	Tenants include 480 growing dura only.
1941–2	35,700	14,316	71,000	9,440	32,629	..	1,888	..
1942–3	35,700	7,882	24,400	9,720	36,153	..	1,944	5,830 feddans wheat also grown.

In 1943–4 the gross area was extended to some 38,500 feddans, by the inclusion of 4,800 feddans of wheat, some 2,800 of which were grown on the fringes of the scheme. This wheat is mainly grown by cultivators outside the scheme proper, but the eventual inclusion of these fringe areas into the general layout will probably take place. The main scheme now comprises 1,967 tenancies, and the 'basic rotation' is in force from the 1943–4 season, but the full area of 'lubia' has not been sown up.

X1730A cotton was sown in 1940–1; Sakel in other seasons. Dura yields are estimated in standard ardebs; cotton yields are actual, in kantars of 315 rotls.

Rotations. The basic rotation for the scheme can best be understood by a reference to the diagram showing rotations at p. 776. The tenant has the option of sowing his 'free feddan' with any crop (including dura) with the exception of cotton. In the earlier stages of the scheme the dura holding was 5 feddans per tenancy and cultivators also had the option of growing dura on their cotton holding. None availed themselves of this alternative, as the cash return from cotton was too attractive. Extra dura areas were grown from season 1939–40 onwards in order to provide for increased

supplies of grain but, as stated above, the basic rotation will be enforced as from 1943–4.

Administration. In the White Nile Alternative Livelihood Schemes responsibility for management and administration has been devolved to the native authorities to a far greater extent than elsewhere in the province. This decision to hand over so much of the responsibility was a bold one, for very few of the tenants or the sheikhs in charge of blocks of cultivation had previous experience of cotton growing or even of irrigation methods. It is proposed to discuss the administrative methods adopted, both agricultural and executive, at Abd el Māgid in some detail, for they apply, with only minor adjustments, to the other Alternative Livelihood Schemes.

The White Nile Alternative Livelihood Board.

Local Consultation Committees:
- 1 for Abd el Māgid.
- 1 for White Nile Pump-schemes.

Canal or Scheme Courts:
- 16 for Abd el Māgid.
- 2 for Hashāba.
- 1 each for Fatisa, Umm Gerr, and Wad Nimr.

Agricultural Sheikhs (the executive authorities).

The Board, whose composition was noted previously, is responsible for the general policy, management, and financial matters affecting the various schemes. It meets as required and the secretarial work, formerly undertaken by the Irrigation Department, is now done by the Senior Inspector of Agriculture for the Province.

The Local Consultative Committees deal with specific problems referred to them by the Board. They are composed of the District Commissioner, Dueim, as chairman, with the Nazir of the Hassania and the local representatives of the Agriculture and Irrigation Departments as members.

Canal and Scheme Courts are analogous, the difference being one of the title only. They are made up of Agricultural Sheikhs, along with one tenants' representative from each sheikhship. They meet weekly under their elected presidents and each has a secretary. The latter official may or may not be a member, as his appointment is based solely on his ability to record the business of the court.

These courts deal with agricultural offences such as infringements of watering regulations, dirty cultivation, &c. They have powers to assess compensation which, after collection, is credited to the tenants' general account of the station concerned. Such awards of compensation are subject to confirmation on appeal by the Omda within whose jurisdiction the court lies.

The Inspector of Agriculture attends the Scheme Courts, reviews the work of the preceding week, and issues instructions for the coming one. For convenience the Abd el Māgid Scheme is divided into four sections, each with its weekly review. The court books are audited at the meetings.

An annual meeting is held on each scheme when major questions of policy are discussed and evictions of unsatisfactory tenants are made.

These meetings are attended by all Agricultural Sheikhs and Tenants' Representatives and, in addition, the District Commissioner, the Local Inspectors, and the tribal leaders are in attendance.

The Agricultural Sheikh is in charge of the members of his village group. The size of the latter varies somewhat according to layout, but at Abd el Māgid may be taken as averaging some 29 tenancies or a gross cultivable area of some 522 feddans, plus the area comprising the village and its precincts. The sheikh's duties are:

To pass on instructions received from the Inspector of Agriculture with regard to planting, watering, harvesting, &c., and to see that these instructions are carried out.

To order water from the Irrigation representative for his block and to supervise its use.

To pay out to tenants the cash advances received, e.g. for hoeing, &c., during crop establishment.

To be responsible, in general, for the running of his group.

The Local Government for the Dueim district is administered by the Nazir and Local Authority for the Dar Hassania. The headquarters are at Naima, and he is assisted by four Wakil Omdas, with their Omdas, Sheikhs, and Village Councils. There is a Wazir who is in charge of accounts and who assists the Nazir with the more technical work such as roads, wells, and buildings.

The Wakil Nazirs are centred as follows:

(i) *North-eastern Wikala*: H.Q. at Abu Gūta, includes Abd el Māgid and Fatisa Schemes.

(ii) *Southern Wikala*: H.Q. at Dueim, includes Hashāba and Umm Gerr Schemes.

(iii) *North-western Wikala*: H.Q. at Wad Nimr and includes that Scheme.

Dueim Town Council is a separate Local Government Authority within the framework of and subordinate to the main Local Government Authority.

On the judicial side the Nazir's Court has powers of imprisonment up to 2 years (3 years for animal theft) and a fine of £E.50. Wakil Nazirs' Courts have powers of imprisonment up to 18 months and a fine of £E.25.

Omdas have powers of fine only, varying from £E.2 to £E.5.

In addition there are panels at Dueim, Geteina, and Kawa with powers of imprisonment up to 2 months and a fine of £E.10. The judicial powers of subordinate courts emanate from the Nazir's court. Appeals from an Omda's Court lie to the Wakil Nazir and from the latter and panels to the Nazir. The Agricultural Courts, &c., noted above are complementary to the Administrative Courts with magisterial powers.

In order to lead to greater decentralization it is hoped to form gradually village and scheme councils. At the latter membership would be open to Government officials closely connected with the scheme, such as the Irrigation Engineer, the School-master, the Public Health overseer, &c. In this way it is hoped to obtain a co-ordination of effort and a community spirit.

A further step towards the community spirit has been fostered by the creation of ploughing societies. The working bulls were originally bought by the Government and tenants were charged a flat rate per tenancy for operations carried out on their land. These societies are now buying back the bulls, providing for ploughmen, and carrying out their own cultivation. Each society has a treasurer who collects from the tenants ploughing charges and amounts in cash and in kind (grain and 'gassab') required for the upkeep of the animals and for the payment of attendants. A margin is allowed in order to build up a reserve fund to replace losses of bulls through castings or deaths.

It will be very obvious from the foregoing that a considerable amount of responsibility has already been devolved to sheikhs and tenants in the running and management of their own scheme, both as village communities and as components of larger groupings.

The Agricultural Inspectors in charge have inevitably had to shoulder extra responsibilities owing to the inexperience of the sheikhs and cultivators. They have had to guide the scheme through its early stages, train and encourage those in charge to undertake new and strange duties, replace the weaker vessels, and generally to inculcate a spirit of co-operation throughout the scheme.

The Tenants. The rights, duties, and responsibilities of tenants are outlined in the 'Tenants' Agreement'. This is too lengthy a document to quote here, but the main points are given in this and the following section.

Each tenant is responsible for the cropping of his holding of 18 feddans in a proper manner and in accordance with the rotation approved. The tenancy is allotted annually, the term being from 1 July to 30 June. Of the crops grown he gets 40 per cent. of the net cotton proceeds, and the grain and fodder produced are entirely his own, free of tax. Each tenant is personally responsible for carrying out his share of watering duties. He is also responsible for the construction and maintenance of laterals, his share of common watercourses, and for sanitation measures required.

He lives in a village laid out on model lines, which is situated near the land which he cultivates. If a tenant neglects his crop it may be safeguarded at his expense or the tenancy is terminated and transferred to a new tenant at an assessed valuation.

The houses were originally constructed by the Government and the tenant paid rent for 3 years, after which the house became his property. The tenant is encouraged to enlarge and improve on the original buildings. Experience has shown that the village group of 29 tenancies (522 feddans of cultivable area) is too small, and villages are now being increased in size.

The allocation of tenancies amongst those dispossessed of their land presented numerous problems, as there were far more claimants than holdings. Settlement of the early instalments was fairly straightforward, but, as the benefits of the scheme became apparent, the application increased in volume and eventually the expedient of drawing names had to be adopted. Allocation of tenancies was on a basis proportionate to the tribe's loss of river land.

Financial Arrangements. In the past, three separate budgets were con-

cerned with financing the Alternative Livelihood Schemes. Those affected were the province (Native Administration) and the Departments of Irrigation and Agriculture. Provision is now largely made in the budget of the last-named. It seems probable that a further centralization and simplification of accounts will shortly be effected by having a separate budget for these schemes as a whole, on similar lines to that of the Gash Board.

Advances are made to tenants, if required, at flat rates, for the establishment of their cotton crop. The payments for cotton brought in differ somewhat from those applying in the concession area, as a flat rate per kantar is paid out, irrespective of grade. To arrive at this price an estimate is made of the total yield by the Inspector of Agriculture concerned. The gross value of this is then calculated by the Department of Agriculture at the prices then ruling. From this total is calculated the net value, after deducting marketing and ginning charges such as transport costs, cost of sacks, ginning costs, storage and insurance charges, &c. The tenant's share is 40 per cent. of the net value of the crop, less cash advances, cost of seed, his share of cotton-pulling costs, and other specified charges. From this figure is struck the price payable per kantar. Any excess which may be realized is passed to the Tenants' Equalization Fund which is used to supplement the tenants' share of the proceeds in bad seasons, or to meet expenditure incurred for the general benefit of the tenants as a whole. A further fund has been created, known as the Tenants' Welfare Fund, by the deduction of one piastre per kantar from the price paid out. The Government thus contributes 60 per cent. and the tenants 40 per cent. of the amount paid in annually. This fund, which is administered by a local Committee of Management and which also has a Board of Trustees, is utilized to provide benefits and amenities lying outside the normal scope of Government activities.

Suggestions have come from the tenants themselves and include the provision of stud stock, the erection of a club at Abu Gūta, adult education, child welfare, &c.

The Agricultural Sheikhs receive a basic payment of £E.1 per month, and, in addition, are paid a bonus (at present 3 P.T. per kantar) for each kantar of cotton produced by their cultivators. In 1940–1 the average payment from the latter source amounted to £E.20.751m/m.s per head. Each Agricultural Sheikh has thus a direct incentive to improve the yield of his group by efficient cultivation and thorough picking. The bonus payments are entirely met from the Government's share of the cotton crop.

The adoption of flat-rate payments for cultivation advances and cotton brought in, and the transfer of any appreciation to an equalization fund, has done away with the need for an elaborate system of individual accounts. It has also greatly simplified the procedure of making payments and of general accountancy, and has enabled the annual balance-sheet to be drawn up with little or no delay at the end of each season.

Garden and Forestry Plots. These have been established in all stations. The former provide supplies of vegetables to local residents and are worked by cultivators who are not tenants in the scheme proper. Low

water rates are charged in order to encourage their development, the annual charges being:

Onions . . .	£E.1.500 m/m.s per feddan.
Other crops . .	£E.1.000 " " "

Onions are the most popular crop and considerable profits can be made by those cultivating them.

Forestry plots have been established and maintained by the Forestry Section: their object is to provide both wood fuel and building poles for the construction of houses. These plots are all sited outside the main rotation area and, in addition, small plots have been sown adjacent to villages to meet their fuel requirements.

General. One of the most interesting experiments attempted is the opening of a 'Borstal Institute' at Abd el Māgid for the detention of prisoners of an unsophisticated type. Here they serve their sentences in surroundings akin to those of their na ive villages. They grow their own crops, are acquiring a communal herd, tlearn the principles of mixed farming and irrigation, and are subject to a minimum of supervision. It is hoped to teach them simple trades such as carpentry and weaving. They also keep their houses in a state of repair.

The response has been excellent and back-slidings have been very few. The scheme has the blessing of the central prison authorities, and it is likely that the success obtained at Abd el Māgid will lead to the adoption of similar schemes elsewhere.

The results that have been obtained to date with the Abd el Māgid Scheme generally are also most encouraging. Abu Gūta, the central village of the scheme, has grown from a mere spot on the map into a well-laid-out village, with shops, school, dispensary, and administrative buildings. Sites have been reserved for a mosque and small hospital. It is now a centre to which the surrounding cultivators gravitate for their simpler requirements. The tenants on the scheme have probably never been so prosperous, but the full adjustment of their mode of life to the new conditions will take time. The scheme has also been an experimental field for trying out the devolution of authority, the system of community working, and the inculcation of new ideas with regard to social services and a general betterment of living conditions which may well form a pattern elsewhere in the Sudan.

7. *Government Pumping-schemes*

The Government pumping-schemes on the White Nile which came into being to provide for alternative livelihood requirements are, in order of their development, Fatisa, Hashāba, Umm Gerr, and Wad Nimr. In general these four schemes are now run on lines very similar to those employed at Abd el Māgid, with minor adjustment with regard to village grouping, rotation in force, size of holdings, &c., which are necessitated by the more irregular character of the land.

The tenants are, as far as possible, found from those local inhabitants whose former livelihood was dependent on lands adjoining these centres.

The Dueim Scheme, which will eventually come under the aegis of the White Nile Alternative Livelihood Board, is discussed in another section (p. 802) as it originated as far back as 1927. It is probable that other alternative livelihood pumping-schemes may eventually be started elsewhere, provided suitable areas can be found. For the moment, however, the war has created difficulties with regard to the provision of the pumping plant, &c., which precludes immediate development.

It is proposed to discuss the existing schemes only very briefly in this section.

(i) *Fatisa.* Started in 1938, when a dura crop only was sown. Gross area is approximately 5,500 feddans, with 337 tenancies.

The scheme is partly on a four-course and partly on a six-course rotation (see diagram at p. 776). The progress of the scheme is shown below:

	Dura crop		*Cotton crop*		*'Lubia' crop*	
Season	*Feddans*	*Ardebs*	*Feddans*	*Kantars*	*(feddans)*	*Remarks*
1938–9	3,059	14,000	..	..	..	Double dura area sown.
1939–40	1,410	9,100	1,347	5,216	862	..
1940–1	1,400	8,600	1,344	3,567	868	..
1941–2	2,212	13,500	1,344	4,081	220	Extra dura sown.
1942–3	1,344	7,400	1,344	4,388	630	238 feddans wheat also sown.

Sakellarides cotton grown throughout.

Eleven Agricultural Sheikhs are responsible for the cultivation and irrigation operations: each has from 20 to 30 cultivators in his group.

(ii) *Hashāba.* Irrigation started in 1939–40: in the previous season a rain-crop of dura was sown. The gross area in 1942–3 was approximately 8,200 feddans, allocated amongst 518 tenants, but from 1943–4 was reduced to 7,300 feddans by the cutting out of some 60 tenancies on inferior land. The main rotation is identical with the Fatisa six-course: no four-course rotation is employed. The scheme is managed by sixteen Agricultural Sheikhs.

	Dura crop		*Cotton crop*		*'Lubia' crop*	
Season	*Feddans*	*Ardebs*	*Feddans*	*Kantars*	*(feddans)*	*Remarks*
1939–40	2,565	9,100	..	..	..	..
1940–1	2,070	8,300	2,037	5,268	1,070	..
1941–2	3,108	12,400	2,072	4,918	340	Extra dura sown.
1942–3	2,072	9,320	2,036	7,144	518	509 feddans wheat also grown.

X1730A cotton sown in 1940–1; Sakellarides grown in the other seasons.

(iii) *Umm Gerr.* Commenced irrigation in 1941–2. Cotton first grown (Sakel) in 1942–3. The scheme in 1943–4 had a gross area of approximately 7,700 feddans, allocated among 393 tenants. The rotation in force

is six-course (see diagram at p. 776). The scheme is managed by fourteen Agricultural Sheikhs.

	Dura crop		*Cotton crop*		*'Lubia' crop*	
Season	*Feddans*	*Ardebs*	*Feddans*	*Kantars*	*(feddans)*	*Remarks*
1941–2	3,537	14,500	..	..	..	1,179 feddans of wheat also grown.
1942–3	1,179	4,700	1,179	4,796	1,179	1,179 feddans of wheat also grown.

It is hoped to extend the scheme by a further 1,000 feddans: a few uneconomic tenancies will be dropped at the same time.

(iv) *Wad Nimr.* This small pump-scheme only started to operate in July 1943. It has a gross cultivable area of some 1,230 feddans. The rotation and size of holdings will be similar to those in force at Umm Gerr. The scheme will accommodate some 68 tenants: an adjoining area of some 150 feddans may later be cultivated by low-lift water-wheels, operating from a short canal linking up with the reservoir.

(v) *Possible Future Developments.* A large area of good land exists near Fashishoya. Smaller areas suitable for development as pump-schemes are situated at Shabasha West and Wakra.

The existing Dueim Scheme of 1,700 feddans can also be extended by about 1,000 feddans and will eventually come under the control of the White Nile Alternative Livelihood Board.

The main field for further development of irrigated areas would, however, appear to lie in future extensions of the Gezira canalization scheme.

8. *Private Pump-schemes on the White Nile*

Amongst the measures proposed to ameliorate the conditions of those whose lands were inundated by the reservoir was the encouragement of private pumping-schemes.

The main development of private schemes has been on the reach of the White Nile lying between Kawa and Kosti.

The various schemes concerned are tabulated below, in their order from north to south. The gross cultivable areas shown are those whose cropping was sanctioned within the bounds of each scheme in 1943. Numerous alterations, exchanges, and additions have been made in the course of the last few years, and it is probable that further changes will occur in the future. Most of the schemes shown are laid out in fields of 5 feddans, the tenancy being 15 feddans: 4-feddan fields are, however, in existence at Gemeilāb, Riād, Gulli, and Tawīla. The rotation is similar to that shown for Dueim in the diagram, but the 'lubia' plots have seldom been sown up in full, as rain-grazing is usually adequate. As with the Government schemes, additional areas of dura have been grown during the war period in order to augment the supply of grain. Only the larger pump-schemes have been included in this list.

Name	Approximate gross cultivable area	Cotton area 1942/3 (feddans)	Started to operate	Remarks
Gemeilāb .	1,900	620	1934	Gross area reduced 1943.
Shabasha East	1,650	500	1940	..
Abu Hindi .	3,000	845	1936	..
Kunuz .	3,400	800	1936	Extended in 1942.
Hassan Allob	1,850	500	1942	..
Riād .	1,800	950	1934	Gross area reduced 1943.
Shawāl .	3,100	920	1935	Extended in 1943.
Gulli .	3,000	945	1934	..
Fageirab .	650	200	1941	Vice Jebelein watered from Gulli.
Jassir East .	2,000	..	1943	Vice Hedeib.
Umm Ghanim	1,600	..	1943	..
Melāha .	7,000	2,200	1939	Extended in 1943.
Tawīla .	2,700	720	1934	..
Hedeib .	..	200	1936	Both schemes originally about 600 feddans. Jebelein closed down 1940. Hedeib closed 1943: replaced as above.
Jebelein .	..	..	1936	
Total .	33,650	..	..	..

Other schemes

Name	Approximate gross cultivable area	Cotton area 1942/3 (feddans)	Started to operate	Remarks
Aba Island .	14,500	2,100	1929	See remarks below.

The Aba Island Scheme is licensed in the name of Es Sayed Sir Abd er Rahman El Mahdi Pasha. It has been in operation since 1929 and cannot be included in the list of pumps providing for an alternative livelihood for those dispossessed of their lands. The island will be very largely submerged at full reservoir level, and the land that may eventually be capable of cultivation by pump irrigation will be considerably reduced. The Melāha licence has been granted to Es Sayed Sir Abd er Rahman in compensation for his losses at Aba, but a number of tenancies have also been allocated in the scheme to provide for alternative livelihood requirements.

It would be wrong to assume that the full area in the preceding list has been utilized for the provision of an alternative livelihood for those affected by the dam. Some of these schemes started to operate before the effects of the reservoir were fully realized by the local inhabitants. A very large area has, however, been taken up by tenants living in the immediate vicinity of these schemes. There is no doubt that the large expansion of irrigated cultivation since 1934 has had a marked effect, both directly by settlement and indirectly by providing employment for picking, &c., on the general welfare of the local population.

9. *Effect of Measures taken to date*

On the Abd el Māgid Scheme some 38,000 feddans have been taken up by 2,000 tenants. On Government pump-schemes a gross area of about 22,000 feddans provides a living for some 1,300 tenants. It is probable that at least an equivalent area, with an even larger number of tenancies (owing to smaller holdings), can be safely assumed for the private pump-schemes. The loss of 'safra' dura has been more than made good by the dura grown under irrigation, and the introduction of cotton as a cash crop has largely increased general prosperity. Those who have obtained tenancies are therefore much better off than they were previously. But a large number of local inhabitants have received nothing to date beyond the cash or rain-land compensation granted them for their inundated lands. The settlement of these outstanding cases will be gradual, as further development will have to await the coming of peace-time conditions, though it is probable that low-lift 'sāqiya' cultivation can be expanded to a limited extent by the employment of local materials. In general it can be said, however, that the change-over from a semi-nomadic life to one of settled cultivation of new crops is in process of successful accomplishment, and that the population fringing both banks of the White Nile will ultimately enjoy reasonable prosperity and an assured mode of life.

Other Government Pump-schemes

(i) *Ed Dueim.* Mention has already been made of the Ed Dueim Scheme (usually known as 'Dueim') in the preceding sections. This scheme of about 1,700 feddans gross area commenced pumping in 1927–8. It cannot therefore be regarded as an 'Alternative Livelihood' proposal, although it will eventually be included in this category. The rotation adopted is similar to that originally employed in the Gezira: fields are 5 feddans each and the holding is 15 feddans. A further 1,000 feddans is available for extension.

In addition to the normal rotation area of some 100 tenancies (1,500 feddans) various plots are cultivated by the Bukht er Ruda Teachers' Training College, the Junior Secondary School, and the Rural Intermediate School. All these institutions have a syllabus with a definite rural bias, so instruction in practical agriculture forms part of the training. Any irrigation water needed for these instructional plots is supplied on a water-rate basis.

Since its initiation Dueim has produced very satisfactory results. It has been directly administered by the Department, but, in anticipation of its transfer to the White Nile Alternative Livelihood Board, two Agricultural Sheikhs have recently been appointed and instructed in their duties.

(ii) *Qundal.* This scheme, more usually referred to as 'Gondal', was originally irrigated by pumps drawing water direct from the Blue Nile. It started to operate in 1925–6; the original licence was issued in the name of Es Sayed Sir Abd er Rahman El Mahdi and Es Sayed Abdullahi El Fadil. Crops were grown in blocks, the rotation allowing for cotton-dura and 'lubia'-rest on the same proportion as the old Gezira rotation. By

1930–1 the gross area had increased to some 2,290 feddans. In the same season the canalization of the scheme was completely reorganized, and new pumps and machinery were installed, drawing water from the main canal instead of the river. In 1934 the licencees transferred their main interests to the White Nile, and Qundal was somewhat neglected in consequence. The lease was therefore terminated in 1936 and the Agricultural Department took over the running of the scheme from the beginning of the 1936–7 season: the running of the pumping plant and the maintenance of major canalization and buildings is undertaken by the Irrigation Department. During the first year of Government control an interim cropping programme was adopted, but the present rotation has continued in force since 1937–8. Originally there were 65 tenancies of 24 feddans. Fields are either 4 or 8 feddans in size, as a uniform layout is impossible owing to soil irregularities. The layout adopted gave a cultivable area of 1,560 feddans, 390 being cotton.

Four Agricultural Sheikhs are in control of cultivation and watering, with a Sudanese Agriculturist in general charge, taking his instructions from the Senior Inspector of Agriculture for the province. The original tenants comprised three main groups, Ta'eishi, Haussa, and Indigenous: model villages for each group were constructed. Since its start, the scheme has been used to try out methods of mixed-farming, improved cultivation, and the devolution of responsibility.

In 1942–3 the cropped areas were extended by the inclusion of a further 19 tenancies (456 feddans). The cotton area is now some 500 feddans: the L cotton types (X1530 and X1730) have been grown throughout and very high average yields obtained.

Much good land also lies to the west of the main canal. An extension of Qundal in this direction was mooted in 1936, but it was decided that the capital costs required for its development were too heavy.

(iii) *Muzeigila, Hag Abdullah, and Wad en Nau.* These three pumping-schemes are directly concerned with the supply of water, both for irrigation purposes and for domestic supplies, to the main Gezira Scheme. They are discussed in the chapter on 'Irrigation'.

Reservoir Areas

The area submerged by the Jebel Aulia Dam has been discussed briefly in the preceding pages. Experiments are still proceeding to investigate the crops most likely to succeed. It may be some time before a programme for the utilization to the best advantage of the reservoir can be evolved. The emptying of the reservoir coincides with the advent of the hotter weather, and the soil is generally of poorer quality than that found on the Blue Nile, and less retentive of absorbed water.

To date forage crops appear to promise best, but it seems likely that some of the higher islands can be employed for the growing of food crops.

The reservoir abounds in fish, and it is possible that this source of food may become of increasing importance in the future.

A more promising exploitation of the artificial conditions created by the reservoir is the expansion of low-lift irrigation, either direct or by channels

carrying water back from the full storage level. Experiments are being conducted in several places to this end, and a cheap and easily maintained form of the Egyptian water wheel ('tabūt') has been designed which holds promise of more general adoption.

On the Blue Nile the Sennar reservoir area has been steadily cropped for a much longer period—since 1926. The emptying of the reservoir begins about 1 February and is completed by May in normal years. Sowing usually begins in March and continues through April. The cultivating season is again somewhat unfavourable and the Blue Nile, after a 'false rise' in May, starts to rise steadily from June onwards. The period available for the ripening of crops is thus fairly short.

There are, however, several factors which favour the production of crops in this area. These are:

(i) The steeper slopes of the river banks, thereby allowing the more rapid sowing of the exposed land.

(ii) The soils are better, and a considerable amount of alluvial silt is deposited during the flood period. The soils are thus more retentive of water.

(iii) The reservoir area lies within the 20–25-in. rainfall zone, and early rains in May and June usually help the growing crops to a considerable degree.

The middle levels are usually those adopted for cultivation and large crops of maize, cowpeas (*Vigna unguiculata* Walp. and *V. vexillata* Benth.), 'bamia' (*Hibiscus esculentus* Linn.), and a few sweet potatoes are grown. Many cucurbits, including water- and sweet melons and various forms of gourd, are also cultivated. These crops have been selected by the cultivators themselves as most suitable for prevailing conditions. Rice (tried on a limited scale experimentally) has proved a failure and dura crops, even quick maturing types, have suffered great damage by birds.

In addition to the cultivation of the main reservoir area, fringe cultivation is also practised to some extent with full reservoir levels. The water required may be provided either by natural seepage or by lift ('sāqiya' and 'shadūf'); in the latter case winter crops are grown, chiefly vegetables, between November and February.

Trapped basins (usually termed 'maiya') exist in many places which might be cultivated if drains were provided. They are mainly utilized, however, for grazing and forests at present.

Rain Cultivation and Grazing Areas

In general it may be said that the production of successful rain-crops requires a rainfall of 400 mm. (16 in.) or more.

The 400-mm. isohyet runs roughly through a line from Kosti to Wad el Haddad–Wad Medani and then swings due east to the Atbara. It is probably most convenient to discuss the cultivation by districts, and this method has been adopted in the following paragraphs.

(i) *The Dueim District.* The rainfall is generally too light for successful cultivation, and the original economics of the district, comprising mainly Hassaniya, are largely based on the river.

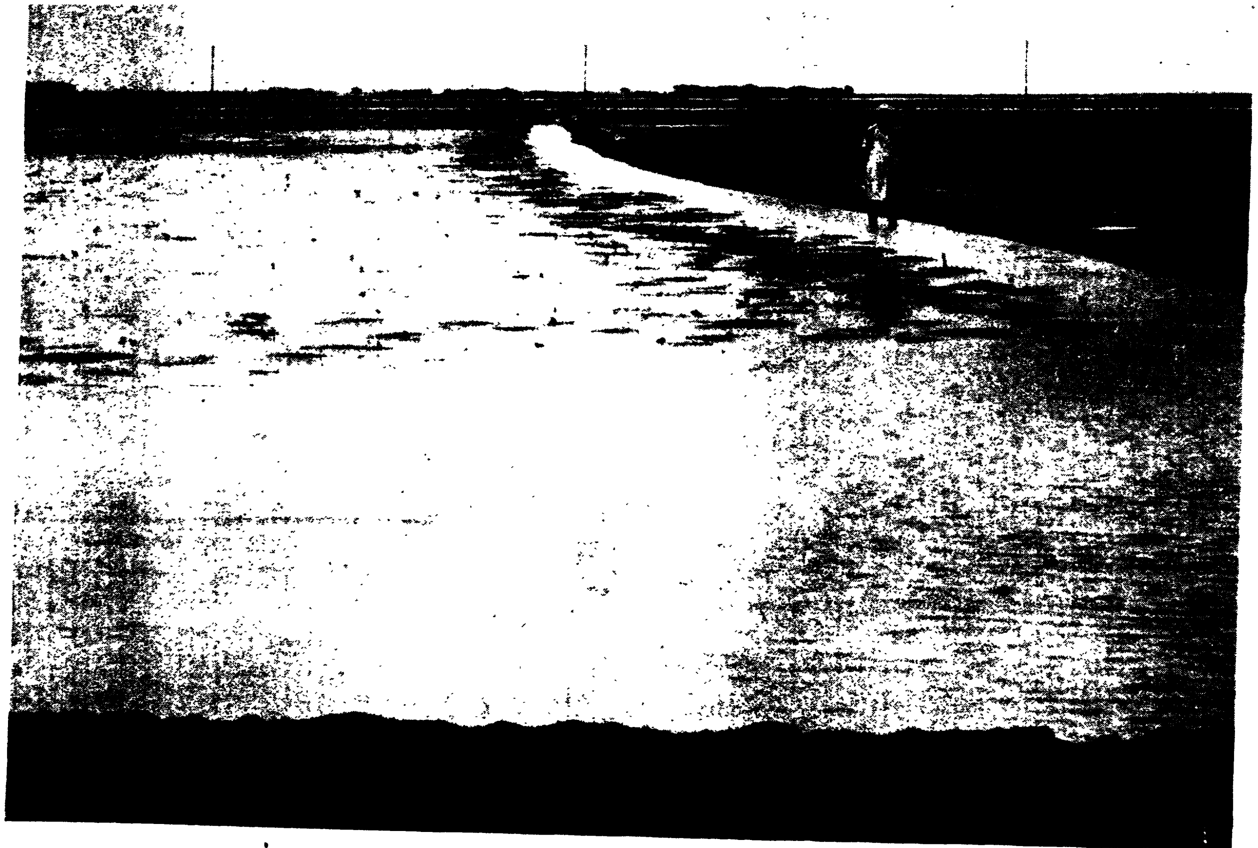


FIG. 311. Rain cultivation: water impounded by low earth banks, 'terūs', for dura cultivation (*photo M. C. Hattersley*).

The effects of the Jebel Aulia Dam and the steps taken to provide an alternative livelihood for this area have already been covered fairly fully in the preceding sections. Ed Dueim has always been a place of some importance and was originally the headquarters of the old White Nile Province. It attracts a good deal of the trade from eastern Kordofan, including much rain-grown dura and simsim, and an oil-mill is kept busily employed.

Kawa borders on the rain zone, but an expansion of pumping-schemes in this area has largely led to irrigated cultivation.

(ii) *Northern Gezira.* The extreme northern portion again suffers from inadequate rainfall and the eastern part is now largely incorporated within the Gezira irrigated scheme.

Mention must be made of the Manāgil region and the area lying between it and the White Nile. This region has established a high reputation for grain-production which is somewhat unexpected, as it lies well to the north of the 400-mm. isohyet. The cultivators by their skill, by the extensive use of the 'terās', and by selecting duras (chiefly of the Feterita type) with a short maturing period, have converted this region into an important centre of grain-production.

(iii) *Rufaa District.* This comprises several local administrations as far south as the Kawahla Nazirate, and the rainfall trends from some 7 in. in the north to over 20 in. in the south. The northern part produces little or no grain; the central portion has usually a large exportable surplus. The southern part is intersected by the Rahad and Dinder rivers: it is less thickly populated, but has a relatively larger livestock population.

The population is mainly concentrated along a strip of varying width following the rivers. Backing this is a relatively waterless area which is utilized both for rain cultivation and the grazing of livestock during and after rains. Irrigation is only practised on a small scale, but the river banks and islands are largely sown up as the flood recedes.

The growing of rain-crops in the Shukriya region requires the employment of the 'terās' and quick maturing dura types (Fig. 311). Feteritas and Gassabi are the main varieties grown. No rotation is practised and the same land will be cropped year after year with enforced resting periods only resulting from the failure of the rains. In the Kawahla Khut a reddish Feterita type is mainly planted. For the 7-year period (1936–42) the average area sown with grain amounted to some 345,000 feddans.

The Rufaa district has a considerable livestock population and the camels of the Shukriya range far into the Butana during the rains. The camels from the Rahad and Dinder also move north into the Butana in the rains to avoid the fly.

Cattle, sheep, and goats graze fairly close to the river and usually cross over to the Gezira between May and September, when grazing is scarce on the east bank.

(iv) *Kosti District.* This district is occupied mainly by Baggāra tribes whose name implies that they are cattle owning. The Baggāra are semi-nomadic and own large herds of cattle, sheep, and goats. Grazing is generally adequate, but local seasonal migrations are common, both to avoid 'fly' and owing to the lack of water in the hinterland during the

summer months. Flocks may thus range as far as northern Kordofan and into the Upper Nile as far as Renk.

The Baggāra are, however, tending to become more settled and to take up cultivation to a greater extent. The land to the east of the river is mainly cracking clay; to the west it trends into the 'qōz' soils of Kordofan.

As the rainfall is generally adequate a considerable number of dura types are grown. The more important varieties include Feterita, Mareig, Hajeraj, Mughbash, and Safra. Dukhn (*Pennisetum typhoides* (Burm.) Stapf and Hubbard) is grown widely near Tendelti, on the railway just east of the province boundary, and simsim is also largely grown on the 'qōz' soils. Ground-nuts are grown extensively near Jebelein and on the west bank, and this crop is increasing in popularity. The average assessed yields (in standard ardebs) for the period 1935 to 1940 have been as follows, in round figures:

Dura 62,000; dukhn 5,800; simsim 9,600; ground-nuts 8,300.

The Baggāra do not willingly part with their cattle, which provide them with milk and semn and are also used for transport. The main trade has been with the Gezira, but the high prices for livestock ruling during the war have resulted in considerable exports to Egypt.

(v) *Sennar and Maiurno Khuts.* Large crops of grain are grown along both sides of the railway line and considerable 'harīq' areas exist. Water-supplies are, however, scanty except along the river and in the neighbourhood of the isolated hills—Jebel Moya, Jebel Dūd, &c.—lying just north of the railway line from Sennar to Kosti. With the improvement of water-supplies, through 'hafirāt' or wells, a large increase in grain and other crops could be effected. Maiurno is a settlement of Nigerians, mainly Haussa and Fulani, under a Sultan of that name. They form an industrious community, growing a wide variety of crops. A considerable number of water holes for water storage have been dug in the Maiurno hinterland away from the hills. To the south of this area lies what was formerly the old 'Fung Province', which was amalgamated into the present province in 1935.

From Sennar southwards the rainfall is adequate for rain cultivation. It is somewhat surprising that the old Fung region does not produce more than it does. There is ample land, a good rainfall, and a natural waterway in the Blue Nile. Grazing is plentiful and forests abound throughout the whole area, but the southern tribes are still very backward. There is little doubt that this region will become increasingly important in the future, as it is capable of great development.

Malaria, deterioration of soils near the river, and the lack of permanent domestic water-supplies are the main causes of poor cultivation.

(vi) *Arab Nazirates.* The three administrations of Kenana—Kawatil, Rufa'a el-Hoi, and Rufa'a esh Sharg—are mainly Arab in origin and consist of both sedentary and nomadic sections. The Rufa'a esh Sharg tribes are mainly camel-owning, but cattle and sheep are increasing whilst camel figures seem to be declining slightly. In dry weather herds graze as far south as Soaleil. Another section, mainly cattle, grazes up the Dinder as far as the National Park (a game reserve). In the rains they move north,

crossing the Rahad and Dinder and penetrating far into the Butana. Their range rather depends on the rains and they may cultivate in the Butana wadis near Jebel Mundara (about 15° N. by 34° 25′ E.) and elsewhere when the rainfall is good.

The tribes west of the Nile are mainly cattle- and sheep-owning: they again may range far in search of grazing. In the rains they move northwards to the Kosti–Sennar railway or even as far as Manāgil. Their 'harīq'

FIG. 312. Grain-stores in the Ingessana Hills (*photo J. F. E. Bloss*).

crops are largely grown near Jebel Dali and the hills adjoining, and are harvested in the winter months.

In the dry months their herds may penetrate to the Khor Yabūs or well into the Upper Nile Province. As with many pastoral tribes, they are inclined to run foul of the cultivator, and the increasing cultivation and settlement in the Jebel Dali area and along the fringes of the reservoir lead to the familiar antagonism between the herdsman who considers trespass a negligible offence and the sedentary farmer who strongly resents it.

(vii) *The Fung Qism.* This irregularly shaped area is now but a faint shadow of the former powerful Fung kingdom. As with most of the divisions in this area, there is a considerable mixture of races. Colonies of Nigerians, with no allegiance to the Maiurno Sultanate, are found in villages along the Blue Nile.

In general throughout this region cultivation may be found in four main

types of soil. These are (i) 'gerf' lands, (ii) 'maiya', (iii) 'kerrib', (iv) 'dahrat'.

The 'gerf' lands are alluvial pockets of very rich soil laid down by the river in flood. They vary in size and are capable of producing very high yield. Grain, maize, vegetables, pulses, chillies, and other crops are found, but many of these pockets are largely undeveloped and are left to grass and forests.

The 'maiya' are basins left by the receding river. As a rule they are also left to grazing and forest, but the fringes are often cultivated. As can readily be realized, they form a happy breeding-ground for mosquitoes, and so are rife with malaria. The 'kerrib' lands are the gullied slopes running from the plains to the river. Erosion is severe and they are therefore not very suitable for the growing of crops, but with well-spaced rains produce very fine crops of dukhn.

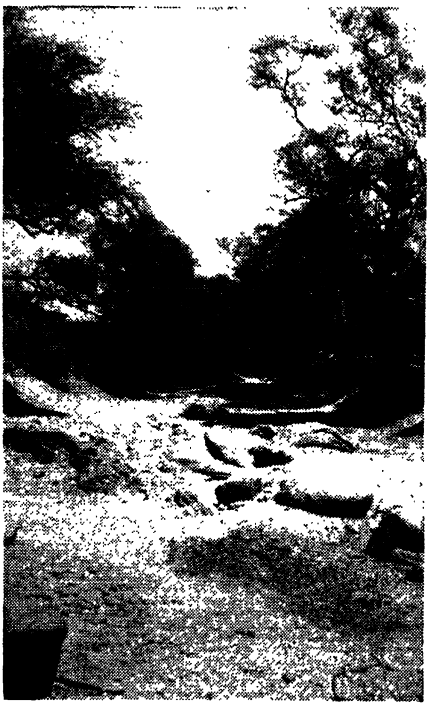


FIG. 313. Khors that are dry for most of the year are numerous in the Sudan. This one is in the Ingessana Hills (*photo F. Crowther*).

The 'dahrat' are the flat plains on both sides of the river, often largely composed of 'cracking clay' and carrying a cover of grass and acacias. These form the main cultivating areas, and large crops of dura and sesame are grown. There is the usual tendency to overcrop the land till soil-exhaustion, clearance of trees, and erosion makes a move compulsory. Er Roseires has an average rainfall of over 32 in., and many good types of sesame are grown in this region. The whole Fung region is capable of much greater production, and steps have been taken to preserve 'harīq' areas, to increase water-supplies, and to develop a greater sense of land values.

(viii) *The Southern Divisions.* The races here consist mainly of a jumble of tribes, many of them backward and unenterprising. The Barun and Watawit present examples of communities whose standards are still in an undeveloped stage.

The Ingessana are the most virile and progressive of the various communities. They occupy the low massif of the Ingessana (Tabi) Hills, grow a variety of crops, and trade many of their products with Roseires. Other tribes which are independent, enterprising, and good cultivators are the Berta living in the hills and the Gumz on the east bank. From Roseires southwards the clay plains gradually trend into the Abyssinian foothills at Kurmuk.

The backwardness of many of the tribes in this area is hardly surprising when their buffer position, between Abyssinian raiders, poaching parties, and the slave gangs from the north in the 'bad old days', is remembered. It is only within recent times that comparative peace has attended their ways: formerly their crops, their herds, and their own bodies were at the mercy of plundering forays, from almost every point of the compass.

Rain Cultivation: General

For the four years 1935 to 1938 inclusive the estimated production of rain-grown dura (in thousands of metric tons) was as follows:

	1935	*1936*	*1937*	*1938*	*Remarks*
Blue Nile and Fung	127·6	92·8	88·5	77·2	Locust damage severe in 1938.
White Nile . .	38·2	38·9	33·5	25·2	Figures for dura and sesame from Annual Reports of the Dept. Economics and Trade.
Kassala . .	36·5	43·7	39·4	31·1	. .
Kordofan . .	101·2	163·4	98·1	70·7	. .
Total . .	303·5	338·8	259·5	204·2	

It will be seen that the Blue Nile Province, which now incorporates the White Nile in its boundaries, produces a large proportion of the dura grown in the main rain areas. Large additional amounts of grain are produced from the Gezira irrigated area and from the White Nile irrigated and river lands. The Blue Nile Province thus continues to function as one of the Sudan's main granaries.

For the same seasons and areas the production of rain-grown sesame was:

	1935	*1936*	*1937*	*1938*	*Remarks*
Blue Nile and Fung	5·0	4·7	4·9	5·4	Figures in thousands of metric tons.
White Nile . .	2·7	2·7	1·9	3·4	. .
Kassala . .	3·5	3·6	8·2	7·9	. .
Kordofan . .	9·7	20·4	27·8	16·4	. .
Total . .	20·9	31·4	42·8	33·1	

There is little doubt that the Blue Nile Province's production figures, both of rain crops and of cattle exports, could be very largely expanded from those shown above.

CHAPTER XXVIII

UPPER NILE PROVINCE

By J. H. SHERWOOD, B.A., DIP. AGR. (Oxon.), *Inspector of Agriculture*

Pay not thy praise to lofty things alone,
The plains are everlasting as the hills.
P. J. BAILEY, *Festus: Home*

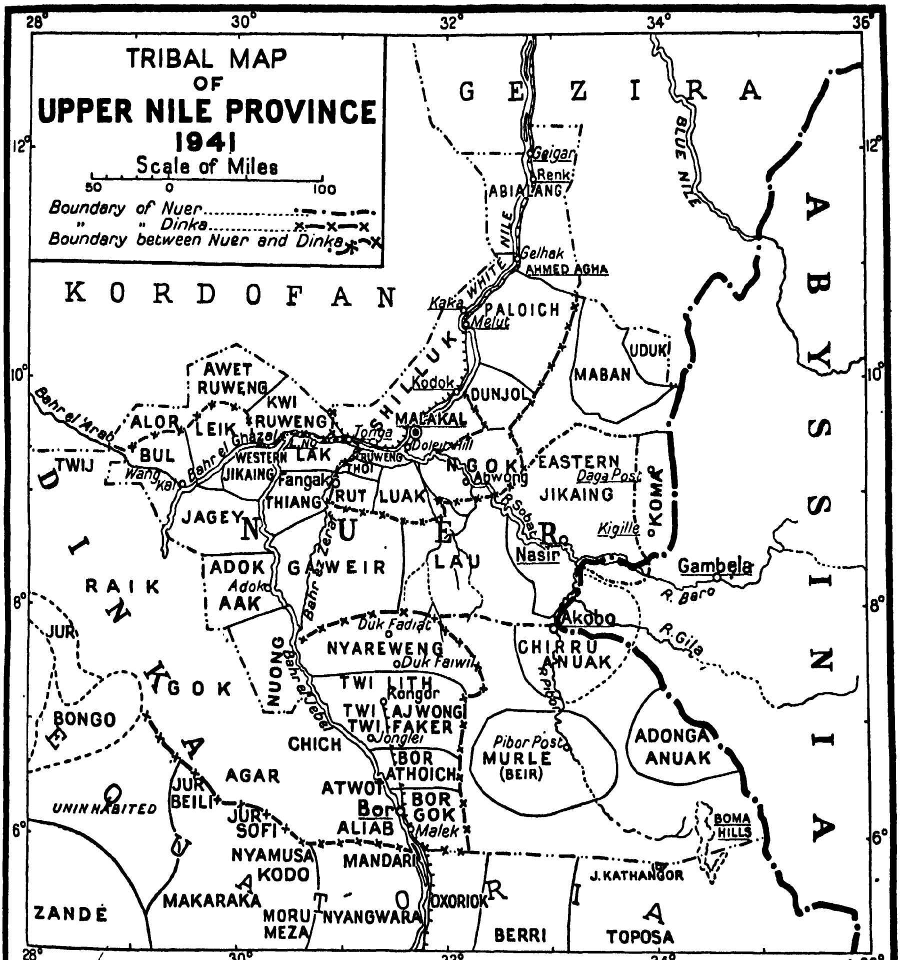
1. *General*

Upper Nile Province, comprising as it does an area of some 92,270 square miles, and populated entirely by pagan negroid tribes, was always regarded in the early days of Sudan history as entirely uninviting and, indeed, generally inaccessible. Infiltration was therefore slow, and even to-day, despite modern transport and enlightened administrative method, it remains the most uncivilized province in the country as a whole.

The famous explorers Baker, Speke, and Grant all passed through in their quest for the source of the Nile *circa* 1860–4. During that period before Anglo-Egyptian administration, and particularly in the grim days of the Mahadia, expeditions were made by armed Arab bands from the north and Abyssinians from the east for two purposes only—the search for negroid slaves and ivory. The remains of their slave camps may still be seen at selected sites in the province. The year 1898 saw a fierce battle against the Dervishes in the Renk area where their camp was attacked and a river steamer captured. In the same year the 'Fashoda incident' almost gave rise to international complications between the existing French and British Governments. Colonel Marchand who, with his small, brave, exploratory force had trekked across Africa from the west, established a small post at the mouth of the Sobat river. Pushing on to Fashoda, he raised the French flag and claimed the explored territory in the name of France. Lord Kitchener proceeded to Fashoda by river from Omdurman with a steamer of troops and eventually had to take the whole force prisoner. Happily, the incident was brought to a close without a shot being fired on either side, and was later diplomatically settled by the defining, once and for all, of the respective spheres of Anglo-Egyptian and French influence, and the withdrawal of the French troops to other climes.

A Government station, under the Anglo-Egyptian administration, was established at Fashoda in 1900 and its name changed to Kodok. The former name is now applied to the Shilluk King's village, 12 miles from its original site. In 1904–5 the Egyptian Irrigation Department established a station at Malakal (Shilluk: 'high cattle camp'), and in 1912 the Government also moved its headquarters from Kodok to Malakal. The latter town (with the small Egyptian Army garrison stationed at Taufikīa, where it remained until 1916) thus became, and still remains, the most important centre in the province.

For administrative purposes Upper Nile is divided into the undermentioned districts and Government stations:



TRIBAL MAP
OF
UPPER NILE PROVINCE
1941
Scale of Miles
50
0
100
Boundary of Nuer
" " Dinka
Boundary between Nuer and Dinka
GEZIRA
KORDOFAN
ABYSSINIA
DINKA
NUER
BAHR EL GHAZAL
MONGALLA
Geigar
Renk
ABIALANG
WHITE NILE
BLUE NILE
Gelhak
AHMED AGHA
Kaka
PALOICH
Melut
SHILLUK
UDUK
MABAN
Kodok
DUNJOL
AWET
RUWENG
KWI
RUWENG
ALOR
LEIK
BUL
TWIJ
Bahr el Arab
Bahr el Ghazal
L. No
WESTERN LAK
JIKAING
Fangak
THOI
RUWENG
Tonga
MALAKAL
Doleib Hill
NGOK
EASTERN
JIKAING
Abwong
Daga Post
KOMA
Kigille
R. Sobat
RUT
LUAK
THIANG
JAGEY
Nasir
Gambela
R. Baro
ADOK
Adok
AAK
GAWEIR
LAU
Bahr el Zeraf
RAIK
JUR
Akobo
R. Gila
CHIRRU
ANUAK
Duk Fadiat
NYAREWENG
Duk Faiwil
NUONG
Bahr el Jebel
TWI
LITH
Kongor
NGOK
BONGO
TWI
AJWONG
TWI
FAKER
Jonglei
R. Pibor
Pibor Post
MURLE
(BEIR)
ADONGA
ANUAK
CHICH
BOR
ATHOICH
AGAR
JUR
BEILI
ATWOT
Bor
BOR
GOK
UNINHABITED
JUR
SOFI
ALIAB
Malek
BOMA
HILLS
NYAMUSA
KODO
MANDARI
J. KATHANGOR
MAKARAKA
ZANDE
MORU
MEZA
NYANGWARA
KOXORIOK
BERRI
TOPOSA
28°
30°
32°
34°
36°
12°
10°
8°
6°

District	Area in square miles	Government stations
Malakal Town . .	..	Province H.Q. and District H.Q.
Northern . . .	22,510	Renk and Kodok (Sub-districts).
Eastern Nuer . .	8,485	Nasir (District H.Q.).
Western Nuer . .	14,175	District H.Q. is on river steamer.
Zeraf	9,885	Fangak (District H.Q.).
Pibor	27,450	Akobo Post (District H.Q.).
Bor	9,765	Bor (District H.Q.).
Gambeila . . .	..	Trading post in Abyssinia.

2. *The Tribes and Population*

The tribes of Upper Nile consist of the Shilluk, Dinka, Nuer, Murlei (sometimes referred to as the Beir), Anuak, Mabaan, Uduk, and Khoma, totalling approximately 520,700 people in all.

The above figure is made up as follows:

Malakal Town .	6,550
Shilluk . . .	80,000
Dinka . . .	165,000
Nuer . . .	212,000
Murlei . . .	30,000
Anuak . . .	15,000
Mabaan . . .	8,000
Uduk . . .	3,000
Koma . . .	1,150
Total . . .	520,700

Fierce, warlike, and resenting external interference, many of the Nilotic tribes have at one time or another proved a source of annoyance to the Government. Until 1929 military patrols were not infrequent and punitive expeditions a necessity. Though from a Central Government point of view pacification is now complete, it is still a major administrative problem to sublimate a perfectly natural hereditary fighting instinct into less exciting, but more peaceful and productive, occupations. Inter-tribal fights on a very minor scale still occur to-day, but more particularly fights within the tribes themselves, section against section. Such affairs rarely produce many casualties, and merely amount to a quarrel, real or imagined, over grazing or fishing rights, the 'borrowing' of a few head of cattle, or even the aftermath of too large a dance and beer party.

The Shilluk mainly inhabit the country close by the river between Tonga and Kaka on the west bank of the Nile, with other small sections between Malakal and the Sobat river. Proud, and reserved almost to the point of insolence to those who do not know them well, they are more sedentary than the Dinka or Nuer and have a tribal organization which differs from that of the other Nilotics except the Anuak, to whom, in the distant past, they were related. Direct allegiance is owed to the king of the tribe and not merely to a large and important section chief. 'The Shilluk King is absolute head temporal and spiritual, of a state whose territory is divided into a number of provinces each administered by a chief directly responsible to the sovereign, and acting as his

FIG. 314. A typical Shilluk village with cattle 'luak' in background (*photo J. H. Sherwood*).

FIG. 315. Nilotic cattle at home in the village (*photo J. H. Sherwood*).

proxy.'[1] A direct descendant of Nyakang, the first Shilluk king, he is afforded the greatest respect and honour, and can dispense justice with a divine right that is his inheritance. The king has his large village at Fashoda, with another small residence at Kodok, the sub-district headquarters. Like his neighbours, the wealth and position of the Shilluk are measured by the number of head of cattle he possesses. An ardent fisherman, he alone attaches great importance to this extra item of diet.

The Dinka, most 'sophisticated' of the Nilotic, possibly due to temperament, adaptability, and proximity to communications, form two blocks: one in the north of the province, and one in the south. There are also two semi-isolated sections, one up the Bahr el Ghazal and one in the Zeraf district. This tribe, with the Nuer, forms the largest cattle-owners in the province.

The Nuer as a tribe have become spread out over a fairly large tract of territory as a glance at the tribal map (p. 811) will show, inhabiting the Ghazal and Jebel rivers, Zeraf, Sobat, and Akobo areas. Cattle-loving, cattle-worshipping, the tribe possesses more head per man than any other Nilotic. It may be said that the Nuer are the most warlike, intransigent, and hardest to administer. In spreading out so far afield they have lost a certain amount of their homogeneity and former tribal organization.

The Murlei are a semi-nomadic people, until recently little administered, living on the Upper Pibor river and its tributaries the Kengen, Veveno, and Lotilla. There is also a small section of the tribe which lives in the Boma plateau country.

The Anuak, in the Sudan, inhabit the banks of the Sobat, Baro, Gila, and Akobo rivers, but the greater part of the tribe live across the frontier in Abyssinian territory. In speaking a type of Shilluk dialect, and in their customs and manner of living, they resemble that tribe in many ways. They also have a king, but there is no absolute allegiance as in the case of the Shilluk. The Anuak has been called the Nilotic with a difference: certainly he is less reticent, more industrious, and a better agriculturist than any of the former tribes mentioned.

The Mabaan and *Uduk* peoples live in the 8,000 square miles round the Yabūs river and its tributaries. On the east they march to within a few miles of the Abyssinian frontier: on the north with Kurmuk sub-district. On the west they march with the Paloc Dinka, and to the south is Eastern Nuer district. The Mabaan and Uduk are quite different tribes speaking different languages and having different customs. They are quiet, peaceful peoples, industrious, and excellent cultivators.

The Koma, who inhabit a small area round Kigille and Daga, are really an offshoot of that little known tribe living across the frontier in Abyssinia. They are administered by Nasir district and latest returns show 700 tax-payers only. They have few animals, and cultivate maize and tobacco.

3. *Physical Features and Rainfall*

Between the various river basins, with the exception of the vast southerly swamp area between Lake No and Shambe, known as 'the Sudd' or barrier, the province is largely composed of flat clay plains, apart from

[1] Seligman, *Pagan Tribes of the Nilotic Sudan*.

those sections of its southern boundary which coincide with the Abyssinian frontier and the Boma plateau. The latter is approximately 4,000 feet high, 15 miles wide from east to west, and 7 miles long from north to south. Only two other raised landmarks exist—a hill of volcanic rock known as Jebel Ahmed Agha on the east bank of the Nile down stream of Melūt, and Jebel Zeraf, a small granitic outcrop a few miles from the mouth of the Zeraf river. Malakal is 1,265 feet above sea-level and Bor 1,379.

The annual rainfall throughout the province varies considerably from 506 mm. at Renk in the north to 992 mm. and 845 mm. in the south at Akobo and Bor respectively. As often as not, although the rainfall may be up to average, incidence of fall is spasmodic, distribution poor, and in consequence crops fail badly. The rains normally begin in late May and end in early October. Average annual rainfall figures for selected Government stations are given below:

Renk . .	506 mm. or 20 in. approx.	
Kodok . .	682 " " 27 "	"
Malakal .	737 " " 29 "	"
Fangak . .	1,178 " " 46 "	"
Nasir . .	804 " " 31 "	"
Akobo . .	992 " " 39 "	"
Bor . .	845 " " 33 "	"

4. *Communications*

River communications naturally form the basis for transport throughout Upper Nile Province. The Main or White Nile is so called only from Lake No to Khartoum, a distance of some 600 miles. At Lake No it splits up into the Bahr-el-Jebel and Bahr-el-Ghazal. The main tributary of the White Nile is the Sobat, which joins it 12 miles south of Malakal. The latter river flows in from the east draining, together with its tributaries the Pibor, Gila, and Akobo rivers, the south-east corner of the Sudan and the Abyssinian foot-hills of the Gambeila district. No important tributaries enter the Bahr-el-Jebel in this Province south of Lake No. Upstream of Lake No, the vast sudd[1] or swamp area begins: miles and miles of sluggish impenetrable sudd stretch as far as the eye can see on either side, and the course of the river becomes more tortuous the farther south one proceeds, until Shambe is reached.

The Bahr-el-Zeraf is, in reality, an eastern arm of the Bahr-el-Jebel and is connected to the latter by a canal, the entrance to which lies approximately half-way between Adok and Shambe.

The Bahr-el-Ghazal is the main exit channel for the numerous rivers draining from the Nile–Congo watershed. This river, like its tributary the Bahr-el-Arab, is sluggish in the extreme, very tortuous, and blocked up with 'sudd'.

It must not be assumed from the foregoing summary of the province waterways that river transport, and communications between river posts, is easy. On the contrary, so seasonal are the majority of the rivers that

[1] 'Sadd', pl. 'sudūd', means barrier in Arabic.

many miles of what appear to be valuable trade arteries are shallow and completely useless for several months a year. For example, the Sobat is only navigable up to Gambeila in a normal year from mid-June to November and to Nasir from May to January. River transport to Akobo is similarly influenced. Likewise, the Bahr-el-Ghazal is navigable sometimes to Meshra-er-Rek only from July to February inclusive. The main Nile, however, is always open for mail freight and passenger services throughout the year.

The Sudan Railways and Steamers run a fortnightly mail, freight, and passenger service from Khartoum to Malakal and Juba with large, stern-wheeler, wood-burning steamers, and Diesel steamers have also been introduced. The province has four stern-wheeler paddle-steamers and two small launches based on Malakal for the use of the various officials. The average draught is in the neighbourhood of 3 feet.

With regard to road transport, there are no metalled roads in Upper Nile Province, the majority having surfaces of heavily cracking, black or dark clay soil. For this reason, during the annual rains from May to October, motor transport is virtually at a standstill. Part of the 'Cape to Cairo' road runs throughout the province, on the east bank of the Nile from Geiger in the north to 30 miles south of Bor where it enters Equatoria Province. Large sections of the road have been graded and embanked, but to make it even 'all seasonal', as opposed to 'all weather', would be a major financial and technical undertaking.

Other main roads radiate from Malakal direct to Nasir, Gambeila, Akobo, and Fangak, and the Sobat river is crossed by means of a pontoon bridge which is removed from May to December to allow for the passing of river craft.

On the west bank of the Nile a main administrative road runs from Tonga to Kaka, via Kodok. Inland, apart from the direct communications mentioned above few good motor-roads exist, and in the Eastern Nuer, Pibor, Western Nuer, and Zeraf districts the usual means of communication for administrative or other purposes during the greater part of the year is by trekking on foot with porters.

Malakal itself has, with increased air transport, become an important refuelling base between Khartoum and Juba on the African Empire Air Route, and caters not only for the Empire flying-boats but also large numbers of other types of aircraft which are accommodated on the extensive aerodrome 2 miles to the north of the town. Emergency landing-grounds also exist at Akobo, Nasir, Wau, and Bor.

All district headquarters are in communication with Malakal by either land line or wireless transmission, with the exception of Fangak and Western Nuer districts.

5. *Vegetation*

Although to-day vast areas of the province are devoid of or very sparsely covered with trees, there is evidence to the effect that many generations ago such was not the case. Following the river valleys and even some distance inland thick forests abounded, with the Acacia species by far the most abundant. Human habitation and annual grass fires are the

elements largely responsible for the open grass plains and scattered 'heglīg' parkland which are the present outstanding features in Upper Nile. The best remaining forest lands are found on the upper reaches of the Sobat and Akobo rivers, Zeraf Island, parts of Western Nuer district up the Bahr-el-Ghazal and southern Bor district, and selected forest reserves have been established at various places on the White Nile.

It is not easy to enumerate all the various trees in the province, and the following short list is merely indicative of the most common and indigenous species which frequently occur. The Arabic name is given first:

FIG. 316. Dōm palms (*Hyphaene thebaica*) are very common in parts of the Upper Nile Province.

'sunt' (*Acacia arabica* Willd.), 'talh hamra' (*A. seyal* Del.), 'talh beid' (*A. fistula* Shwfth.), 'hashab' (*A. senegal* (L.) Willd. and *A. glaucophylla* Steud.), 'lebbak' (*A. lebbek* Benth.), 'kakamūt' (*A. campylacantha* Hochst.), 'harāz' (*A. albida* Del.), 'kūk' (*A. sieberiana* DC.), 'kitr' (*A. mellifera* Benth.), 'la'ot' (*A. orfota* (Forsk.) Schweinf.), 'kadada' (*Dichrostachys glomerata* Hutch and J. H. Dalz.), 'heglīg' (*Balanites aegyptiaca* Del.), 'gamēz' (*Ficus sycomorus* Linn.), 'zan' (*Cordia abyssinica* R. Br.), 'dolēb' (*Borassus aethiopum* Mart.), 'sahaba' (*Anogeissus schimperi* Hochst.), 'dōm' (*Hyphaene thebaica* Mart.), 'aradēb' (*Tamarindus indica* Linn.), 'mahagaya' (*Celtis integrifolia* Lam.), 'sidr' (*Ziziphus* spp.), and 'lebūn' (*Euphorbia* spp.).

The most important grasses from a grazing and domestic economy point of view are: 'burdi' (*Typha* spp., 'Sudd' grasses), 'nagīl' (*Cynodon dactylon* Pers.), 'koreib' (*Dactylotenium* spp.), 'umm sūf' (*Echinochloa colona* Link.), 'sad' (*Cyperus* spp.), 'umm khirr' (*Brachiaria obtusiflora* Stapf.), 'rūz' (*Oryza bartu* O. Chev.), *Panicum* spp., *Sorghum* spp., and *Hyparrhenia* spp., all of which are in abundance throughout the province.

6. *Cattle and Grazing*

Cattle-owning forms the most important part of the Nilotic's existence: so predominating is this interest over all others that his social development has been negligible. After the cessation of the rains, when the grass is drying off, the Nilotic herdsman moves with his stock down to the river, where grazing is rich, and there remains throughout the winter until the beginning of the next rainy season. Despite the fact that, to the casual traveller, the province appears at certain times of the year one vast grazing area, in reality, owing to inaccessibility and swamp, and the

FIG. 317. Nilotic bull with small hump and short horns. (*photo J. H. Sherwood*).

consequent heavy overstocking of the accessible areas, adequate grazing for all still remains an unsolved problem in certain districts. On account of the seasonal variations of the various rivers it is not possible to define permanent grazing areas: generally speaking, in the dry season, sites closely follow each side of the river banks within the tribal boundaries and the rich land surrounding the small khors or tributaries, known as 'toiches'. Cattle are also grazed on large rich islands in the rivers which are more numerous than at first might be imagined, particularly in the south of the province.

The ravages of rinderpest and pleuro-pneumonia, the two most prevalent diseases, help to keep in check the cattle of those sections whose stock is on the increase beyond economic, if not social, limits. Trypanosomiasis and foot and mouth disease also exist, but cattle plague causes the highest mortality.

The present cattle population is put at the conservative estimate of 849,000 head. During the rainy season the cattle inland are herded out to graze under the watchful eyes of youths and young men not engaged in

tending their cultivations; at night they are brought back to the village and herded into huge grass and mud, cone-shaped buildings known as 'luak'. Small slow-burning dung fires are lit inside to keep away mosquitoes and flies.

In the dry weather cattle camps, the cattle are brought in after grazing and individually tethered for the night with large wood and dung fires at selected intervals. Dung is collected daily and dried for this purpose. The Nilotics sleep with their cattle, generally in the shelter of a semi-

FIG. 318. Swimming cattle for grazing.
(*photo J. H. Sherwood*).

circular grass fence which usually surrounds the camp to the windward side.

On the whole the cattle are rich milkers, having a butter fat content of over 4 per cent., but poor quantity producers, 5 pints a day being unusual. An average Nilotic steer will kill out at about 6 cwt. of excellent beef, dead weight, and despite the Nuer and Dinkas' reluctance to sell, large quantities of cattle on the hoof have from time to time been exported north. The average price of a beef steer in normal times is £E.3–4.

In marriage dowries, cattle play the predominating part, and it is interesting to note that the bride-price varies from 12 head of cattle in the Shilluk country to 20, 30, and even more in the case of the Nuer and Dinka. The Shilluk never seem to have completely recovered from previous raids and the ravages of rinderpest, and to-day remain the poorest, yet no less fanatical, cattle-owners in the province.

7. *Agricultural Practice and Agricultural Education*

The most extensively cultivated crops in Upper Nile Province are dura (*Sorghum vulgare* Pers.) and maize. Other crops of lesser and limited cultivation are simsim (*Sesamum orientale* Linn.), ground-nuts, cotton, beans (*Phaseolus* spp.), and tobacco. Their cultivation is straightforward and does

not in general differ from the usual method of raingrown cultivation followed in the southern Sudan, discussed in chapters XV, XVI, and XXXI.

Shifting cultivation is, however, prevalent everywhere. After cultivating the same land for a period of 4 to 6 years, the cultivator abandons it and moves on to another piece, resting his former land for anything up to 12 years or more. As rotations are not practised, and manuring unknown, it will be appreciated that large tracts of previously excellent grain country have thus become seriously deteriorated and non-productive.

FIG. 319. Hoeing a dura cultivation (*photo J. H. Sherwood*).

With the exception of perhaps the Shilluk country, between Tonga and Kaka, most of the large grain cultivations lie some distance inland, away from the river. Small quick-maturing maize crops are planted by the women in the early rains of May and June, while the men go off to plant up their dura cultivations. Two crops of the latter are grown—the early crop which is harvested in September, and the late crop, harvested in December. Ratoon crops of the early dura are also taken in a good rainy season.

Generally speaking, the cattle-owning Nilotic is an improvident and poor cultivator, growing only barely enough grain, with the minimum amount of work, to maintain him and his small family until the following season. In a bad year, when crops fail, the hunger situation becomes acute and often necessitates the undertaking of famine relief by the Government and the importation of grain from the north.

The growing of cotton as a cash crop was first introduced in 1923. It was thought at the time that not only would the money so gained by the native help him to pay his taxes and purchase small amenities of life, but

also, with increased cultivation, an important and valuable export crop would be established. Cultivation has been entirely voluntary, but the interest of the cultivator, even at its peak, was never keen and has dwindled to indifference.

The largest crop ever produced for the whole province, and that mainly by the Shilluk, only amounted to 760 tons raw cotton. From the returns obtained over a 20-year period, it was realized that under present condi-

FIG. 320. A cattle-owning Nilotic.
(*photo J. H. Sherwood*).

tions the crop would never merit the erection of even a small ginning factory in the province, and Upper Nile cotton has always been sent some 500 miles north for roller-ginning at Sennar. Moreover, the cotton (American long staple) was found to be of rather inferior quality, and recently it has been decided, for economic reasons, to abandon the crop temporarily if not permanently.

Steps are now being taken to popularize the increased cultivation of sesame on a cash-crop basis, with a view to establishing oil-presses to satisfy local needs. The province consumes fairly large quantities of sesame oil and the majority of this has to be imported from the north. Moreover, once the crop has become universally popular, diet will be improved, and ready markets are always available for any exportable surplus.

FIG. 322. A Shilluk fishing party.

FIG. 323. Casting a fishing net in the waters of the Upper Nile.

quantities of gum Arabic and tobacco are also exported. In normal times the greater part of the western Abyssinian coffee crop finds its way to market by means of transport via the Sobat and Nile river routes, and the small enclave of Gambeila, leased to the Sudan Government, is largely maintained for this purpose under the control of a British District Commissioner.

FIG. 324. Emptying a fish-trap.

On the import side dura (*Sorghum vulgare* Pers.) and sesame oil are the only two of any note, and in line with current policy steps are being taken to try and make Upper Nile self-supporting in this respect.

Conclusion

Still in the pastoral stage of development, the Nilotic's interest in agriculture as a means of improving his standard of living is negligible. His present needs are extremely simple, and the appreciation of or demand for money as a purchasing agent does not exist. Apart from the Shilluk and certain Dinkas, who wear a single piece of cloth rather like a Roman toga, clothing is not considered a necessity. Incredible numbers of both sexes of the tribes go completely naked with the exception of the married women who wear a small leather apron fore and aft.

The normal Nilotic diet is appalling. For example, citrus fruits and bananas are never cultivated, tea, sugar, and coffee unknown, and being such a hoarder of cattle, sheep, and goats, the meat ration is scanty owing to a reluctance to kill except at ceremonies of religious or tribal signifi-

cance. Lack of salt is remedied by the periodic bleeding of cattle for blood-drinking, and by the constant pollution of milk by introduction of cattle urine. From the foregoing it will be realized that the Nilotic suffers not only from sub-nutrition but malnutrition also.

On the one hand, the province contains vast reserves of cattle and of good agricultural land with a suitable climate for the growing of crops such as dura and simsim. It is true that there are physical difficulties such as the lack of domestic supplies of water in areas remote from the river in the north and that much of the cracking clay soil of the south is subject to annual flooding in the rains. On balance it can be said that despite these difficulties the province has ample physical resources to enable it to become not only self-supporting in the matter of food but to enable it to make a material contribution to the productivity of the Sudan as a whole primarily by the annual sale of surplus cattle augmented by dura and simsim.

On the other hand, all the pastoral peoples in the province are by custom and temperament extremely conservative and are content with their age-old way of life. There is practically no rural demand for education, better and more varied food, medical services, agricultural services, or for trade goods. There would be demand for veterinary services designed to control cattle diseases, but unless such a service could be coupled with a plan for the annual sale of surplus cattle it might result only in increasing the cattle population beyond the capacity of the pasturage.[1]

In these circumstances no rapid economic development in the province can be anticipated, and it seems likely that the desire for social emergence is likely to be kindled only as a result of the gradual spreading of education.[2]

[1] A plan for linking a veterinary service for the control of disease with annual sales of surplus cattle was suggested by the Soil Conservation Committee in its report published in 1944.—*Editor.*

[2] It seems possible that the ever increasing demand in the Sudan for more funds for the social services may cause the development of some of the great reserves of good agricultural land in the Upper Nile Province to be brought about with the use of heavy agricultural machinery and a minimum of man-power.—*Editor.*

CHAPTER XXIX

KORDOFAN PROVINCE

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Area, Population, Administration, &c. (as at 1941)

District	*Area (square miles)*	*Population*	*Government stations*
Central . . .	3,110	86,481	El Obeid (Province and District H.Q.).
Northern . . .	60,225	203,213	Bara (District H.Q.). Sodiri (Sub-District H.Q.).
Eastern . . .	9,235	182,664	Umm Ruaba (District H.Q.).
Western . . .	44,115	369,333	En Nahud (District H.Q.). Ginning factory at Lagowa.
Western Jebels . .	7,030	192,610	Dilling (District H.Q.). Kadugli (Sub - District H.Q.). Ginning factories at Dilling and Kadugli (2).
Eastern Jebels . .	23,215	278,761	Rashad (District H.Q.). Talodi (Sub-District H.Q.). Ginning factories at Talodi, Kalogi, Abu-Gebeiha, and Um Berembeita.
Total . . .	146,930	1,313,062	

The province headquarters are at El Obeid, which, with its population of 33,328, ranks as the largest town in the Sudan after Omdurman and Khartoum. Its railway station is the southern terminus of the railroad.

Produce

Exports from Kordofan consist entirely of agricultural or forest produce. The table on p. 828 will give some idea of the amount of commodities produced in excess of local requirements. The figures are based mainly on a record of dispatches from Kordofan railway stations, but must be considered as being approximate only.

Historical Summary

There is considerable doubt as to the origin of the name Kordofan. MacMichael,[1] however, considers it most probable and natural that it is Nubian in origin, as, in the past, the Nuba ruled the land. Their last king

[1] Most of this historical summary has been based on MacMichael's *The Tribes of Northern and Central Kordofan.*

is said to have lived near J.[1] Kordofan, a few miles south of El Obeid. Most authorities seem to agree that the country has taken its name from the hill (jebel).

Little is known of the history of Kordofan prior to the Egyptian invasion of the Sudan in 1821. The ancestors of the Nuba probably inhabited most of the province in the times of the Pharaohs, who doubtless raided, or traded with, them at intervals. In the thirteenth century A.D. the Arabs started to penetrate into the Sudan, and the original

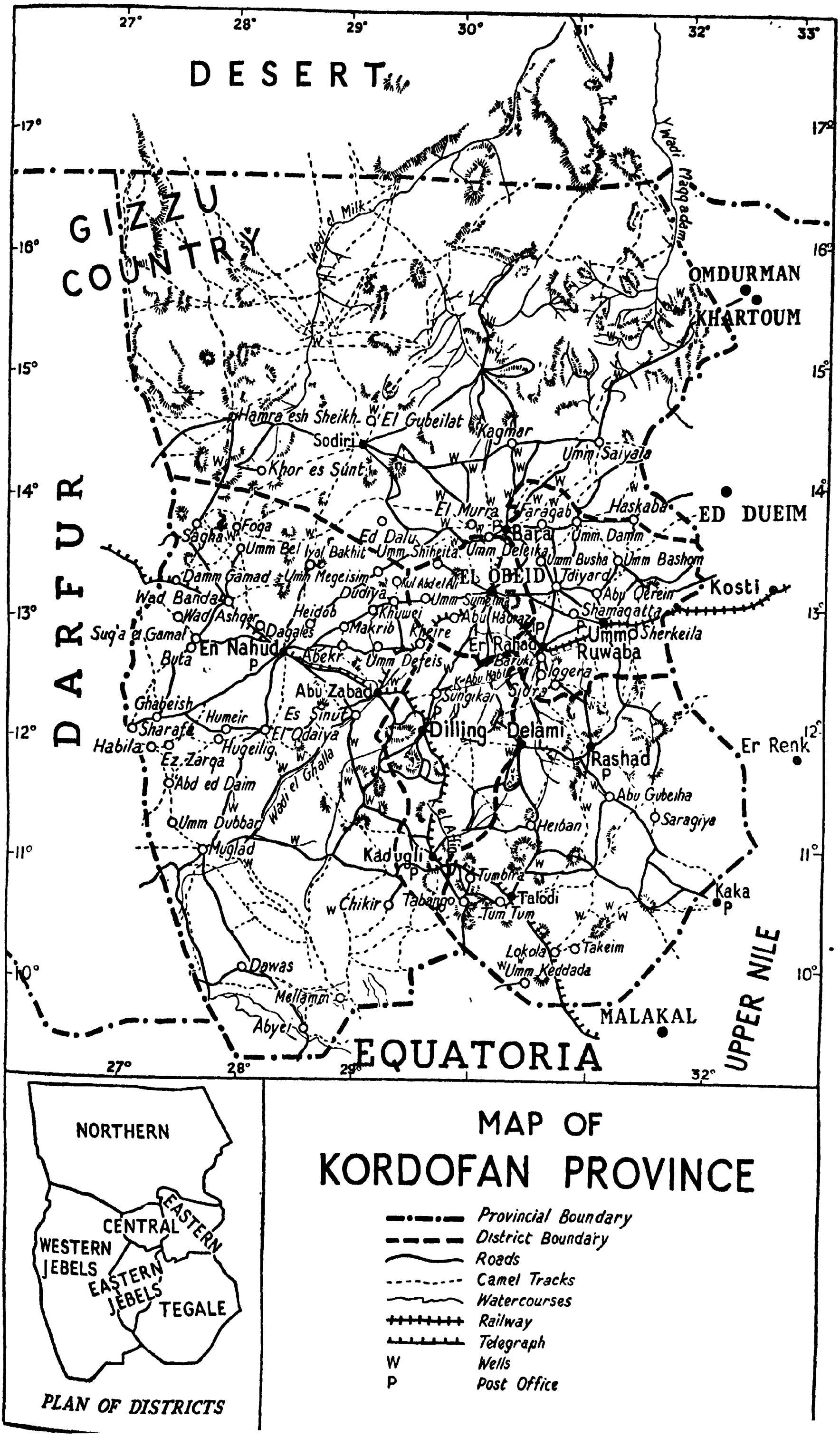
Item	*Average 1932/6*	*1937*	*1938*
	Tons	*Tons*	*Tons*
Gum	13,427	12,967	14,644
Grain	18,214	20,629	17,599
Ground-nuts	2,155	3,017	3,588
Sesame	4,209	8,752	7,855
Melon seed	5,463	5,264	6,215
Cotton-seed oil	..	..	206
Cotton (ginned)	..	3,865(*a*)	4,580(*b*)
Hides and skins	..	500	465
Semn (clarified butter)	..	1,000	1,000
Sesame oil	..	1,500	3,500
	Head	*Head*	*Head*
Camels	..	7,000	5,000(*c*)
Cattle	5,155	11,431	10,628(*c*)
Sheep	..	4,000	4,000(*c*)

(*a*) Production of the 1936/7 season.
(*b*) " " " 1937/8 "
(*c*) This trade in livestock is potentially much greater. The Director Sudan Veterinary Service considers that 20,000 cattle, 100,000 sheep, and probably 20,000 camels could be exported annually if the requisite demand arose. In fact, 30,000 cattle, 200,000 sheep, and at least 30,000 camels were exported during 1941 owing to demands occasioned by the war.

inhabitants of Kordofan were gradually either absorbed or displaced, some of them being pushed south into the Nuba Mountains, where they were able to barricade themselves and retain their entity.

In 1821 Mohamed Ali, the ruler of Egypt, sent Mohamed Bey Defterdar with a force of 4,000 cavalry, 10 guns, and about 1,000 Bedouins to invade Kordofan. He was met to the north of Bara by the raw Kordofan levies to whom fire-arms were unknown. They put up a good fight, however, and only broke when they lost their leader Mekdum Musallem. In a few days the whole of Kordofan, with the exception of the Nuban Mountains, had surrendered. Its conquerors (usually spoken of as 'the Turks') initiated a reign of terror at once, administering the country, in defiance of every law of humanity and justice, entirely for their own personal benefit. When the heavy taxes levied could not be paid in cash, grain, or cattle, slaves had to be delivered instead. Actual raiding for slaves in the Nuba Mountains by organized military expeditions was undertaken annually, and by 1839 by this means alone more than 200,000 had been led into captivity.

[1] J. = Jebel, or more accurately Gebel (hill or mountain).



MAP OF KORDOFAN PROVINCE

After the death of Mohamed Ali in 1854 things improved a little, but extortionism and slave-trading still continued and in 1865 there was a terrible famine.

In 1877 Gordon was appointed Governor-General of the Sudan and did his best to stop the trade in slaves. After his resignation in 1879 it was at once covertly renewed; strangely enough, efforts to stop it had become very unpopular amongst some of the inhabitants of Kordofan—the Baggāra (cattle-owning Arab tribes) in particular. The officials were

FIG. 325. Baggāra Arabs dressed up in antique chain mail attending local festive gathering.

for the most part as corrupt and unprincipled as ever, the country had been robbed of all its wealth, and justice was a farce. The limit of endurance had been reached, and the people were ripe for rebellion.

In 1881 a certain religious teacher, Mohamed Ahmed, arrived at Jebel Gadir, about 60 miles almost due east of Talodi, and openly proclaimed a 'jehad', declaring himself the Mahdi expected of all believers. He defeated two expeditions sent against him by the Government, thereby gaining prestige and large numbers of adherents. These enabled him to lay siege to El Obeid and Bara by about the middle of 1882, the garrisons of which surrendered to him in January 1883.

Shortly afterwards the reconquest of Kordofan was ordered by the Egyptian Government, and General Hicks left Khartoum with an ill-disciplined force numbering 10,000 men and 10 guns. He reached Sherkeila by way of Dueim on 14 October, and his whole force with the exception of 300 men was annihilated at Shekan, about 35 miles south of El Obeid, on 5 November.

Gordon returned to Khartoum in February 1884 and at once acknowledged the Mahdi as Sultan of Kordofan; the latter, however, merely replied with a demand for surrender and marched north with most of the Arab population of Kordofan on 22 August. Khartoum fell, and Gordon was killed on 26 January 1885.

The Mahdi died in June 1885 and was succeeded by the Khalifa Abdullahi. Until he was killed in November 1899, over a year after the battle of Omdurman, Kordofan went through terrible times. The Arabs were drafted away from their homes to fight the Khalifa's battles, some of which were against the Nuba. The result was that very little cultivation was possible and famine resulted. The decimation of the population in this period must have been enormous.

In December 1899 the present Sudan Government appointed its first Governor of Kordofan. Since then the inhabitants have gradually become reasonably prosperous and no serious disturbances have occurred. At first minor military expeditions were often required in order to tame the unruly Nuba. In 1924 a vigorous attempt to turn their 'swords into plough-shares' was started and the growing of cotton as a cash crop was introduced. This caused the opening up of the country and a network of roads gradually sprang into existence: this in turn enabled the Nuba to contact the world outside his mountain fastnesses, resulting in his gradually losing his inherent distrust of all strangers which had been bred in him through centuries when every man's hand was against him trying to grasp him for a slave.

The Nuba Mountains area of southern Kordofan was administered as a separate province with headquarters at Talodi during the period 1913 to 1929.

Physical Features[1]

If the line of the railway from Tendelti to Rahad be prolonged so as to meet the province boundary with Darfur at about lat. 11° 20′, it will form the approximate dividing line between the sandy steppes of the north and the hills and clay plains and valleys of the south.

To the north of lat. 14° 30′ the country has no importance from the agricultural point of view except as a grazing area for camels, cattle, sheep, and goats. The rainfall is light, but is usually sufficient to support low scrub and some of the more drought-resistant herbs and grasses.

A large area in the north-west known as the Gizzu,[2] much of which lies in Darfur and northern provinces, provides in some years luxurious grazing from October to March and occasionally for longer. Camels grazing there do not require watering during the whole of this period (6 months), and the Arabs herding them drink only camels' milk, as the area is without water-supplies during the grazing period.

The country lying south of lat. 14° 30′ and north of the line described in the last paragraph but one consists almost entirely of undulating sandy

[1] See map on p. 829.

[2] A most interesting account of this area is given by Newbold in *Sudan Notes and Records*, vol. vii, nos. 1 and 2, 1924: 'A Desert Odyssey of a Thousand Miles' and 'A Note on the Gizzu or Juzu'.

soil known locally as 'qōz'. It produces large quantities of gum Arabic 'hashab' which provides a lucrative cash crop for the inhabitants. This 'qōz' soil, which is able to absorb immediately all the rain which falls on it, also produces surprisingly good crops of dura (*Sorghum vulgare* Pers.), dukhn (*Pennisetum typhoideum* (Burm.) Stapf and Hubbard), ground-nuts (*Arachis hypogaea* Linn.), and simsim (*Sesamum orientale* Linn.), but it is too light for cotton. Uncultivated 'qōz' generally supports a thin covering of grass and herbs, and a fair stand of light to medium bush, the commonest varieties of which are *Acacia senegal* Willd. (the 'hashab' gum tree), *Balanites aegyptiaca* Del. ('heglīg'), *Acacia raddiana* Savi. ('seyal'), *Ziziphus* sp. ('sidr'), and *Acacia albida* Del. ('harāz'); 'tebeldi' trees (*Adansonia digitata* Linn.) are fairly common, and in some districts their hollow trunks are used as cisterns for the storage of water.

There is one comparatively small area in this belt which is atypical. It is situated near Bara and is known as the 'Kheiran' (plural of *khor* = river-bed). Its interest lies in the fact that it produces considerable quantities of vegetables which are irrigated by 'shadūf' or water wheel from shallow wells. The area is described in detail by MacMichael in vol. iii of *Sudan Notes and Records*, 1920. In addition to onions and the more common varieties of vegetables the following crops are recorded as having been grown satisfactorily in the 'Kheiran': wheat, garlic, capsicum ('shatta'), fenugreek ('helba'). Date palms (most of them males), dom palms (*Hyphaene thebaica* Mart.), and sunt trees (*Acacia arabica* Willd.) are fairly common.

The southern area of Kordofan, which lies to the south of the line referred to in the first paragraph of this section, enjoys a heavier and more reliable rainfall than the rest of the province. In general it may be described as a black or brown clay plain in which rise the mountains and hills known as the Nuba Mountains. These usually consist of rugged granite boulders of very varied shapes rising to a height of a few hundred feet up to 3,000 feet above the plain, which is itself from 1,400 to 2,200 feet above sea-level. In some cases these mountains are isolated knobs, in other cases they are formed into huge jumbled masses; again in others they can be described as formed into definite ranges. Sometimes the rocks are bare of vegetation, though parts of all hills support some sort of a covering of trees, and also of grass for part of the year; the latter is almost always burnt every year shortly after the rains have ceased to fall. A few hills are entirely covered with grass and trees.

There are large areas of soils near the hills which have been formed by the gradual weathering of the rocks. These may vary from what is practically a fine gravel to a light loam. Locally they are classed generally as 'gardūd', as opposed to the clays which are called 'tīn'.

Most of the hills are heavily terraced; the terraces thus formed will produce quite good crops of the earlier maturing duras, but they are not cultivated now to anything like the extent they used to be, the general state of public security allowing the Nuba to cultivate farther afield on the richer soils without fear of molestation.

The clay soils are the richest, but their use for cultivation is limited by their distance from villages, lack of water-supplies during the dry season,

and the fact that some of them become waterlogged during the rains. The whole area of the Nuba Mountains is covered by a network of khors (river-beds). Most of them drain to the south and their waters gradually collect into several main drainage lines, which may be definite river-beds or swampy valleys. Except possibly for water which may reach Lake Abiad (about 40 miles south-west of Talodi), none of it reaches the Nile. The rivers just fade out into swamps, and large areas of land which might be cultivable are ruined by being waterlogged during the growing season.

The better 'gardūd' soils produce very fair crops, but are more liable to suffer from drought than the clay soils as they do not absorb rain quickly: the run-off during a storm is very marked and, in consequence, erosion is common.

The typical tree of the clay soils is the 'talh' gum tree (*Acacia seyal* Del.). The best agricultural soils are those which have a natural cover of this tree with the addition of 'heglīg' (*Balanites aegyptiaca* Del.).

The 'gardūd' soils support a very varied flora, the Combretums ('habil', &c.) being much in evidence. A fairly common tree, used largely by the natives in the building of their houses, is *Anogeissus schimperi* Hochst. ('sahaba'). A very common tree on the more gravelly 'gardūd' soils near the hills, and also on the hills themselves, is the 'tarak tarak' (*Boswellia papyrifera* A. Rich.). It produces a resin not unlike frankincense, but it is of no commercial value.

Rainfall and Water-supplies

There are no records of the rainfall for that part of the province lying to the north of lat. 14° 30′. The following figures have been extracted from reports issued by the Sudan Meteorological Service:

Place	*Average monthly rainfall*									*Average annual rainfall in mm.**	*Period covered by averages*
	Mar.	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*		
El Obeid	1	2	17	38	98	121	75	16	..	368	1901–40
Bara	..	..	8	25	93	116	50	10	..	302	1908–40
Umm Ruaba	..	..	15	31	122	132	55	12	..	367	1912–40
Er Rahad	..	2	21	36	116	131	65	23	1	395	1908–40
En Nahud	..	5	27	43	100	123	86	18	1	403	1911–40
Dilling	2	12	55	94	175	163	129	47	2	679	1915–40
Rashad	2	18	72	99	159	189	165	96	8	808	1915–40
Heiban	3	33	83	108	184	181	172	97	4	865	1928–36
Kadugli	1	17	77	125	154	150	143	86	6	759	1910–40
Talodi	4	23	87	117	157	176	157	85	8	814	1915–40

* 1 in. = 25·4 millimetres.

The first five places included in the above table are situated in the undulating 'qōz' belt lying between lat. 14° 30′ and the railway–Darfur boundary line described previously in the section entitled 'Physical Features'; the last five places all lie in the Nuba Mountains. It will be noted that July, August, and September are the months of heaviest rainfall. It is on the rainfall of these three months that most of the crops rely, though in the Nuba Mountains quick maturing grain crops are grown on light land near the people's houses, often on terraced hill-sides, during May, June, and July.

During the rains surface-supplies of water are plentiful over most of

the province. These soon dry up in the north, and then supplies are limited in those latitudes to wells which are often few and far between.

In the southern half of the undulating 'qōz' country the numbers of deep wells supplying good water have been greatly increased due to Government initiative during the last two decades. The only river of any size draining to the north from the Nuba Mountains—the Khor Abu Habl—is a very important source of water for this area. It fills a lake at Sherkeila, and also probably affects the water-supplies as far as Tendelti in years of heavy rain.

The southern third of the province, which includes the Nuba Mountains, contains numerous sources of water-supply in the form of lakes (e.g. Keilak and Abiad), springs known as 'saraf' which generally occur at or near the base of hills, wells of varying depths, excavated tanks called 'hafirāt', large pools known as 'fula', and natural rock-cisterns on the hills. A few of the rivers (khors) continue to trickle all through the dry season, and in some others water can usually be found by digging holes in the bed. In spite of these comparatively numerous sources of water, large areas of clay soil which are very suitable for growing crops cannot be cultivated owing to their distance from sources of drinking-water. Much has been done to discover new sites for wells in and around these areas during recent years, but it appears that the problem will not be solved by this means alone. If a large increase in the population should demand it and the necessary funds were available, much might be done by building dams at the exits of some of the larger valleys in the hills, thus forming reservoirs which might be gradually emptied during the dry season. They might be utilized to convert seasonal streams into permanent ones, or the water might be conducted into specially dug drinking-water canals. In certain cases a pipe-line might be justified. Furthermore, such dams would be potential sources of electric power. Taking a long view, the making of these reservoirs would be justified before the increase in population makes the demand for them urgent, as, in addition to the benefit noted above, they would lessen erosion and reduce the swamp areas, which would benefit the health of the people and would make possible the cultivation of soils which are now waterlogged annually. Communications during the rains would also be improved.

Tribal Divisions

The map on page 829 shows the Native Administrations of Kordofan. The inhabitants of this province can be divided roughly into the following divisions:

1. Nomad Arabs.
2. Sedentary Arabs.
3. Baggāra (cattle-owning) Arabs.
4. Nuba.
5. Tagali people.
6. Dagu.
7. West Africans.
8. Dinka.
9. Eliri people.

Most of the *Nomad Arabs* inhabit the northern third of the province. They own large numbers of cattle, sheep, and goats, but their chief interest lies in their camels, of which they possess very large herds. The most important nomad tribe is the Kababish, and their administration has recently absorbed the Kawahla. The Hawawir inhabit a comparatively small area in the north-east of the province. Another nomad tribe of importance is the Shenabla, who inhabit the rolling 'qōz' country in the Gawamaa administrative area. The Kababish breed their camels more with an eye on the 'meat on the hoof' trade to Egypt than on their use for transport purposes.

FIG. 326. Baggāra Arabs moving camp (*photo F. Crowther*).

The most important tribes of the *Sedentary Arabs*, such as the Hamar, Bideiriya, Gawamaa, and Dar-Hamid, inhabit the gum-producing 'qōz' lands in the centre of the province, but pockets of people belonging to such tribes as the Kawahla and the Kenana are found in the Nuba Mountains. The former, though of course originally nomadic, have become sedentary: they inhabit several hills round Kalogi, where they are present in considerable numbers. A large pocket of the latter is situated at Abu Gebeiha.

The *Baggāra Arab* tribes consist of the Mesiriya,[1] Humur,[1] Hawazma, Habbania, and Awlad Hemeid. They inhabit the country which lies to the south of the line (railway–Darfur boundary) described in the first paragraph of the section entitled 'Physical Features'. During the rains they live and graze their animals in the northern part of this area. After the rains they gradually move south as grazing and water becomes scarce in the north. In addition to cattle, sheep, and goats, considerable numbers of horses are owned by the first three tribes mentioned above. A glance

[1] Recently amalgamated under the one name of Mesiriya.

at the map on page 829 will show the 'dar' (home country) of the same three tribes. The Habbania live round Lake Sherkeila and have been included under the Gawamaa administration. The Awlad Hemeid are a small tribe, now absorbed into the Tegali Administration, living around El Sheg which is about 50 miles north-west of Kaka.

Since the abolition of slaves and the introduction of cotton as a cash crop, all these tribes, with the exception of the Habbania, have become

FIG. 327. Baggāra Arabs moving camp (*photo F. Crowther*).

large growers of that crop. They use their bulls for pack transport: details of this will be found in the chapter entitled 'Transport in the Sudan'.

The *Nuba* inhabit the mountainous area bearing their name. They are a negroid community speaking several different languages and many different dialects of the same. The great majority are pagan, though some have come under Moslem influence, and there are now a number of Christian mission stations situated amongst them. They vary considerably from hill to hill, but on the whole they are cheerful, often of good physique, suspicious of strangers but very friendly to those whom they know, and they are reasonably good cultivators. They are keen hunters, and one of their chief ambitions is to own a rifle. Few of them wear clothes

FIG. 328. Woman with household effects on the move.

FIG. 329. Taking grain to market (*photo G. J. Fleming*).

except on special occasions, and many of them build themselves, judged by African standards, remarkably good houses.[1] Their villages are usually situated on the tops of the hills or mountain masses or on the outward hill-slopes. They own fair numbers of cattle, sheep, goats, and donkeys. Their cattle are usually of a smaller type than cattle owned by Arabs, and the Koalib section possess small numbers of a diminutive breed which is

FIG. 330. Baggāra Arab who has just delivered two dōm palm matting containers of cotton at a local market. Note the typical Baggara spear used among other things for balancing the load. The saddles have no girths and a man or woman always rides a loaded bull. Incidentally women do not carry spears and appear capable of balancing the load without them! (*photo G. F. March*).

immune to the Tsetse Fly (*Glossina morsitans* Westw.; Arabic 'umm boganī') which is found in the northernmost hills in their area. Their national sport is wrestling. The various communities, which are quite independent of one another, are usually ruled by a 'Mek' assisted by a council of elders, but the witch-doctor ('kugur') often possesses greater influence, as it is he who is believed to control the rainfall, and he decides the time for the sowing and harvesting of crops and many other important questions.

A full and interesting account of the kingdom of *Taqali* is given by Elles in Part I, vol. xviii, 1935, of *Sudan Notes and Records*. The present Mek of Taqali is the nineteenth of his line, which was started about 400

[1] Cf. p. 196, vol. xiv, 1931, Part II, *Sudan Notes and Records*.

years ago by his ancestor, a wandering preacher of Islam, who came from a riverain tribe in the north. The Taqalawi of to-day have developed from a mixture of the blood of the ancient inhabitants, who were akin to the Nuba, with the blood of immigrants from almost every race in the northern Sudan. They have always been stout fighters and have managed to defend their hills and preserve their entity against the many attempts to subjugate them. The ancient kingdom of Taqali comprised the greater part of southern Kordofan, but after the re-occupation it only consisted

FIG. 331. Nuba woman carrying grain-basket (*photo G. F. March*).

of the Taqali Hills and the country immediately surrounding them. Recently, as will be seen from the map on page 829, the Taqali administrative area has been increased so as to embrace much of the old kingdom. The present Mek, with the approval of the Government, has encouraged the settlement of considerable numbers of West Africans on the plains lying to the north of Abbassiya which is the headquarters of his administration. The Taqalawi are good cultivators, generally speaking sturdy and virile, and all profess the Moslem faith.

The *Dagu* inhabit some of the hills on the western fringe of the Nuba Mountains in Dar Mesiriya. MacMichael[1] describes them as 'a miserable remnant of a great race'. Their origin appears to be uncertain, but they attained considerable power in Darfur in the fifteenth century.[2] They are

[1] H. A. MacMichael, *The Tribes of Northern and Central Kordofan.*

[2] Notes on the Dagu will be found in *Sudan Notes and Records*, vol. viii, 1925; vol. xiv, 1931; and vol. xv, 1932.

a black race, sedentary, fair cultivators, but, on the whole, not very reliable. Their chief settlement is at Dar el Kebir.

There are a large number of settlements of *West Africans* in Kordofan. Many of their members only remain for a short period on their way to or from the pilgrimage; but large numbers are permanently settled. Since 1912 records show that immigration has been on a considerable scale. The success of rain-grown cotton in the Nuba Mountains attracted considerable numbers, and immigration and the size of settlements had to be restricted, as the future land requirements of the local population were being jeopardized. Settlement in the Taqali area has, on the other hand,

FIG. 332. Koalib Nuba sitting outside a grain-store.

been encouraged owing to the abundance of land there. With the exception of some of the Borgu these West Africans are usually docile and law-abiding, and they are very good cultivators. Berdab near Kadugli is an example of a successful agricultural settlement, but its size has had to be restricted for the reason given above.

The *Dinka* only occupy a small area in the south-west of the province and are of no importance from the agricultural point of view.

The original inhabitants of the *Eliri* or El Liri Hills are Nuba, but during the Dervish régime a number of ex-slaves of the Hawazma and Kawahla settled there and have since been joined by others. They live in a number of villages at the base of the hills. They are known as 'Elirawi' and have earned a reputation as labourers, not so much for the excellence of their work, but due to the fact that they will undertake labouring jobs, whereas their neighbours the Shilluks on the White Nile are not easily persuaded to undertake work of this kind. They are very fair cultivators, and in addition to dura, cotton, and simsim, grow groundnuts on the light sandy soils near the hills.

Communications and Transport

Exports from the province are carried mainly by rail and river, but

lorries and camels also come into the picture, and livestock often goes out on the hoof.

The main centres for rail traffic are El Obeid, Rahad, and Umm Ruaba. Produce for transport by river is loaded at Tonga or Kaka.

A glance at the map on page 829 will show a considerable network of roads. None of them are metalled, and most of them in the southern half of the province are impassable during the rains except in some cases by light traffic which is subject to delay after a storm.

FIG. 333. The above two photographs were taken at a 'Nuba gathering' at Talodi (*photos C. E. Fouracres*).

Internal carriage is by lorry, camel, ox (pack), donkey; and head carriage is commonly in use in the Nuba Mountains.

Details of these various forms of transport are given in the chapter on Transport.

Details of the Post and Telegraph offices situated in the province may be found in the *Sudan Almanac* which is published by His Majesty's Stationery Office, London.[1]

A Short History of Agricultural Development in the Nuba Mountains

The only area of Kordofan in which personnel of the agricultural section of the Department of Agriculture and Forests have worked for any length of time is the Nuba Mountains, which, in addition to the districts

[1] Also obtainable from the Sudan Agency, 6 Midan Tewfik, Cairo.

now known as Eastern and Western Jebels, also includes a strip of western Kordofan lying to the east of Khor Shalango.

In pursuance of the policy of 'turning swords into ploughshares' (referred to previously in the section entitled 'Historical Summary') the Government decided, in 1923, to endeavour to introduce the growing of cotton as a cash crop. Several meetings took place in London between representatives of the Government, the Sudan Plantations Syndicate, the British Cotton Growing Association, the Empire Cotton Growing Corporation, and a group of Lancashire spinners.

FIG. 334. Rain-grown cotton in the Nuba Mountains (*photo F. Crowther*).

Various schemes were discussed, and early in 1924 a party consisting of the Financial Secretary, the Director of Agriculture and Forests, representatives of the Sudan Plantations Syndicate, Dr. H. Martin Leake, Col. A. Birtwistle, and others made a tour of the Nuba Mountains. It was left to Mr. Eckstein (later Sir Frederick), Chairman of the Board of Directors of the Sudan Plantations Syndicate, to put forward a proposal for the formation of a company to introduce cotton and to run the industry on commercial lines. After due consideration he found that he was unable to produce a workable scheme, though he appeared to be satisfied that cotton would grow well. It was accordingly decided that observational plots of American type cotton should be grown by Government during the rains of 1924. The results were promising, and it was decided that the Department of Agriculture and Forests should go ahead and endeavour to establish a cotton-growing industry.

Production for the 1925/6 season totalled 13,000 small kantars (100 rotls) of seed cotton. The following season this figure was doubled. About that time a further attempt was made to initiate a company which would finance and handle the growing cotton industry. This resulted in a scheme being put forward to the Governor-General in Council, whereby

the British Cotton Growing Association and the Empire Cotton Growing Corporation were to take equal shares with the Government in a company whose object was to be the buying, ginning, and marketing of cotton grown in the Nuba Mountains and also any other cotton grown in the southern provinces. Council, however, considered that the formation of such a company should be deferred, on the grounds that it was impossible to foresee exactly on what lines the cotton-growing industry ought to be handled in the best interests of the local growers and of the country generally. It was therefore decided that it would be preferable for the Government to retain a free hand and keep the industry under its sole direction at least for the time being.

Thereafter production increased rapidly and eight ginning factories were erected in the more important centres. By the 1934/5 season a crop of 406,820 small kantars of seed cotton had been produced, and it had become evident that with the existing population and existing type of husbandry a crop, varying according to the suitability of the season, of between 300,000 and 500,000 small kantars of seed cotton might be expected provided that the price payable to the grower did not drop below an average of about P.T. 35[1] per small kantar of seed cotton.

During the early years the agricultural staff were forced to concentrate on increasing the area under cotton and on organizing the most economic methods of handling the crop when grown. When propaganda for more cotton was being spread, care was taken to emphasize the principle that it should not be grown instead of dura (*Sorghum vulgare* Pers.), the main food crop, but in addition to the usual areas under food crops. This advice was acted upon by the cultivators and the results have been satisfactory to all concerned. The main factor which appeals to the cultivator with-regard to cotton is the fact that he receives the full official price for it in cash immediately he hands it over at the ginning factory or at a weighing centre. Prior to the introduction of cotton his only cash crops of any importance were dura and simsim (*Sesamum orientale* Linn.). He received very low prices for both and was seldom paid in cash. Beads and salt were the most common forms of barter, and, needless to say, the Arab purchasers got very much the better of the bargain!

By about 1929 the industry had become established and the agricultural staff were able to turn their thoughts to the improvement of the local forms of husbandry in order to increase the general standard of living. Experimental farms were started at several ginning centres. Good results were obtained from ploughing and it was hastily assumed after a few years' trial that the future of agriculture lay in teaching cultivators to use the plough and to grow their crops on some sort of a rotation. Various rotations were favoured, e.g.

3-course	*3-course*	*4-course*
Cotton	Cotton	Cotton
Dura	Dura	Dura
Legume	½ Legume	Legume
	½ Simsim	Fallow (land ploughed in the early rains and again after rains).

[1] P.T. 35 is the equivalent of about 7*s*. 2*d*.

Various demonstration plots were laid out in an endeavour to show the benefit to be derived from farming in this way. Very few of the cultivators evinced much interest in them, and those who did very soon lost it. There is no doubt that it was a mistake to try and popularize western methods of agriculture on the assumption that they must be suited to local conditions. No one could be certain of this until after they had been tried out over several decades. It soon became clear that such a radical change in methods of husbandry, even if such a change had been proved to be advantageous, would entail an impossible amount of supervision and would not be adopted willingly by the cultivators in general.

FIG. 335. A local Nuba cotton market. Note the parcel of money attached to the waist of the Nuba in the foreground (*photo G. F. March*).

About 1938 the thoughts of those responsible for agricultural policy began to run on much sounder lines. Instead of trying to popularize a form of agriculture which is quite foreign to the inhabitants, they said let us study the existing mode of life in detail and see if we cannot raise the standard of husbandry, and thereby of living, by building on the foundation of existing methods rather than by trying to introduce systems which, however sound they may turn out to be eventually, would not be adopted readily by the conservative and backward cultivators concerned.

A start was accordingly made by the intensive study of the economics of the daily life of particular village communities, and by the setting aside of an area of approximately 270 feddans, at Dam Gamad near Talodi, on which attempts could be made to devise methods of improving existing systems of husbandry. Unfortunately shortage of staff due to the war has made the carrying out of village surveys impossible. (The results of two which were completed before the war are published in the departmental annual reports for 1937[1] and 1938.[2]) It has, however, been possible to carry on the area (referred to above) at Dam Gamad. It has been named

[1] Pages 65–7: 'Umm Dual', by E. S. Colman.
[2] Pages 105–9: 'Turtur', including a note of land tenure by H. A. Graves.

the 'Talodi Investigation Area'. Various rotations are being tried out, but probably the most useful investigations being carried out, at any rate as regards the not too far distant future, are those concerned with 'harīq' cultivation[1] and the devising, and use of, simple forms of bull-drawn implements which could be made locally. As regards the former, it has already been shown that a good cover of 'harīq' grass can be obtained in one season if seed of suitable varieties of grass is sown, whereas the natural regeneration of 'harīq' grasses takes 3–4 years. It is, however, not yet known if the sowing of 'harīq' grass seed is an economic proposition, nor if the fact that it grows well after sowing is an indication that the fertility of the soil, and in particular the nitrogen content, has been built up at the same time.

The cotton grown is American type with a staple of $1\frac{1}{16}$ in. to $1\frac{2}{16}$ in. in length. Before being imported into the Sudan it had been grown for some years in Nyasaland. It was grown for many years by irrigation in the Northern Province before being sown in the Nuba Mountains. A number of other varieties have been grown on the local experimental farms in conjunction with the Plant Breeding Section of our research organization during the past 15 years. Egyptian long-stapled varieties including Sakel have been tried. They grew well, but produced practically no cotton, the obvious inference being that the growing-season was too short for them. Until recently none of the imported varieties tested had shown any general marked superiority over the main crop, which is known as the 'Pump Scheme variety'. Two varieties, one from Uganda and the other an American type from India, were bulked up in the past and one ginnery area was devoted to growing them. They did not take on commercially, however, and were dropped after a few seasons. The Plant Breeding Section has had a local station at Kadugli during recent years in charge of a plant-breeder loaned by the Empire Cotton Growing Corporation. His work is showing signs of bearing fruit, and, if we can get resistance to blackarm disease (*Xanthomonas malvacearum* (E. F. Sm.) Dowson) bred into some of his most promising selections, cotton production should benefit materially.

In addition to cotton local experimental farms have been used for growing the local food crops and useful data regarding them have been obtained. Imported varieties of many crops have been tried also. No very startling results have been obtained, but heavy yielding dukhns (*Pennisetum typhoides* (Burm.) Stapf and Hubbard) from West Africa have done well and seed from them has been bulked and issued to local cultivators. A useful type of ground-nut from French Equatorial Africa has also been treated in the same way.

The general lines upon which the cotton industry is conducted are as follows:

The only seed which may be sown is that issued by Government. It is issued free to cultivators. During the growing-season the agricultural staff, in so far as it is possible considering the scattered nature of the cultivation, gives advice to growers and takes any practicable action to combat pests. The stainer bug (*Dysdercus* spp.) is one of the worst pests,

[1] For an explanation of this type of cultivation see page 292.

and a campaign against it is conducted just before the rains set in. Most of this work is done by native assistants of the Entomological Section. The bugs congregate on the trunks of 'tebeldi' trees (*Adansonia digitata* Linn.) at this time, and the control consists of spraying them when they are in this vulnerable position. Very few of them (comparatively) are able to exist through the dry season; consequently spraying them at the end of it results in most of the survivors from the previous season being eliminated. This form of control has been very successful and very little stained cotton is brought into ginning factories.

FIG. 336. Women lined up with their baskets of cotton for classification at Kadugli Ginning Factory (*photo L. E. James*).

Generally speaking, the earlier the rains allow of cotton being sown the better the crop. May sowings are risky, June sowings are normally the best, and any sowings done after the middle of July are unlikely to produce good results. When new land is opened up, the cultivator lops off the branches of the larger trees, leaving the trunks standing. If the area in question is suitable for cultivation by the 'harīq' method, he does nothing more until the time comes to burn the grass. If there is an insufficient cover of grasses suited to the 'harīq' system, he burns the branches which he has lopped off the larger trees together with any grass or shrubs encumbering the land. After he considers that the rains have really broken, and after the land has had a good wetting, he sows his seed with a 'selūka'[1] stick after, in the case of the 'harīq' system, burning the grass. Germination is generally good, and in consequence, in order to avoid subsequent thinning of stands, many cultivators only sow 3–4 seeds per hole. During the growing-season three or four hoeings are usually necessary except on the 'harīq' areas, where, if the burning has been effective, much less cleaning is required.

Picking of the crop becomes general towards the end of September and

[1] For details see p. 278.

the Government usually commences to take over cotton in October. At most of the ginneries cotton is taken over on 5 days each week, Fridays are holidays, and Thursdays are used for making up accounts, &c. When cotton is taken over at distant weighing stations, weighings take place perhaps once a month during the season. Every endeavour is made to ensure that a cultivator obtains cash for his cotton immediately he brings it in, and most of the ginneries are provided with special Avery dial weighing-machines which enable the actual weighing to be done very quickly.

FIG. 337. Cultivators weighing in their cotton at Kadugli Ginning Factory (*photo L. E. James*).

Before weighing takes place cotton is classified into four different grades. Usually about two-thirds of the crop is grade I, a quarter grade II, and the remainder mostly grade III. There is very little grade IV. Different prices are paid for the various grades in order to ensure clean picking. Experience over a number of years has shown that cultivators are normally satisfied with the following prices for seed cotton delivered at ginneries:

Grade I . .	P.T. 37	per small kantar	of	100 rotls[1]
Grade II . .	P.T. 34	,,	,,	,,
Grade III . .	P.T. 32	,,	,,	,,
Grade IV . .	P.T. 28	,,	,,	,,

Based on costings applicable before the war, these prices necessitate an average price of about 5·85*d.* per lb. *ex* warehouse Liverpool, or 5·10*d.* per lb. *ex* store Port Sudan in order to cover expenses. This excludes any charge which the Government may make in respect of the running of the industry by the permanent agricultural staff, part of whose time is employed on this work. This charge usually works out at the equivalent of between 0·20*d.* and 0·30*d.* per lb. of ginned cotton.

[1] 100 rotls = approx. 99 lb.

Nuba cotton has usually commanded a price of about ½*d.* to 1*d.* better than the ruling quotation for near position American futures on the Liverpool cotton market. As it is necessary to hold the cotton for varying lengths of time between the time it is bought from cultivators and the time it is sold, it has often been possible to ensure against a loss, due to a sudden fall in the world's cotton prices, by the sale of futures in the Liverpool cotton market. The policy as regards dealing in futures, which has been gradually evolved as a result of experience, is normally never to cover a

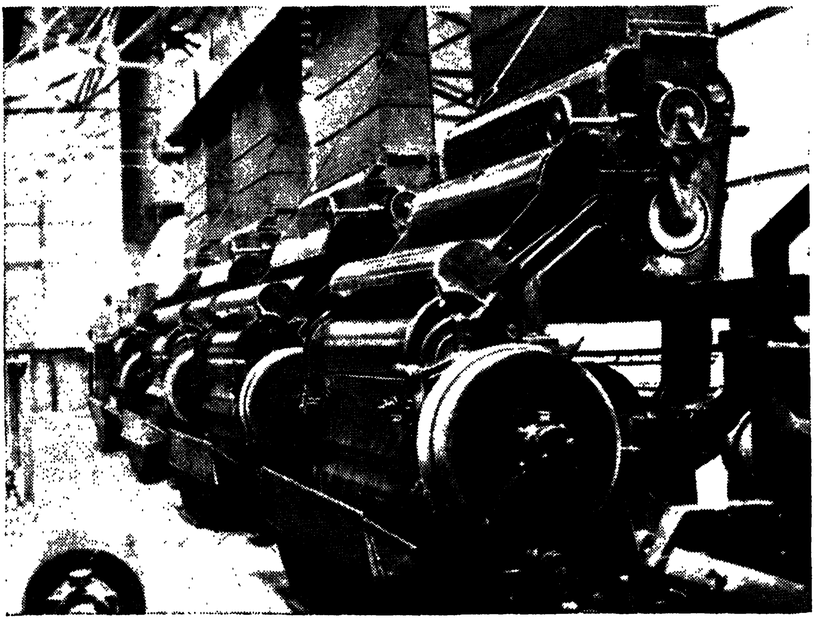


FIG. 338. Interior of gin room at Talodi. The plant consists of a battery of five Dobson and Barlow saw-gins.

loss in order to ensure against a greater one, but, if a profit can be ensured, to cover 50 per cent. or more of the crop.

Any profit which is made on the sale of Nuba cotton is passed to an equalization fund which may be used to bolster up the price paid to cultivators when the world value of cotton is low. This fund was in credit to the extent of over £E.230,000 in 1942. The industry is, therefore, in a very healthy condition and should be able to weather comfortably any slump in world prices which is likely to occur.

Most of the Nuba cotton is made up into fully pressed half-sized bales containing about 240 lb.; a small portion, however, is contained in half-pressed full-sized bales holding about 200 lb. Two of its most interesting characteristics are its cleanliness and the fact that it produces a stronger yarn than would be expected from its length of staple. It is all ginned by saw-gins. There is no market for the surplus cotton seed as the cost of transport to the coast exceeds its value for export. A small oil-mill has, however, been erected at Kadugli which is the largest centre for

cotton.[1] It has worked profitably since its erection. The seed at other centres is eaten by the local herds of cattle and forms a very useful addition to their diet when good grazing becomes scarce, as it usually does by about February each year.

The Khor Abu Habl

This khor obtains its water from the Nuba Mountains. One arm originates in the Dilling neighbourhood and the other near Delami. These two arms join near J. Daier south of Rahad. The main khor then flows

FIG. 339. Cotton lint emerging from the condenser on to the baling platform at Talodi Ginning Factory (*photo T. Trought*).

from west to east roughly parallel to the railway. At Sherkeila it flows into a depression which is thereby turned into a lake except in years of very light rainfall. In years when rains are heavy the khor continues beyond Sherkeila and sometimes reaches Tendelti.

Rather over 20 years ago consideration was given to a proposal to grow American-type cotton on land flooded by this khor. Like many silt-bearing streams, its bed is higher than much of the adjacent land, which, for the most part, consists of a very heavy clay soil. It therefore appeared to be quite a simple matter to flood considerable areas. Cotton was in fact grown for several years. Crops varied from a few hundred to about two

[1] Due to reasons connected with the second world war this mill has been dismantled and re-erected at Sennar, where a larger quantity of seed is available for milling.

thousand small kantars of seed cotton. The lint was well reported on in Lancashire. This production of cotton took place when prices for that commodity were ruling high; when the subsequent slump occurred cultivators ceased to wish to grow it. All cotton growing ceased about 1927.

The chief difficulty encountered in connexion with such cotton as was grown was that, though it was comparatively easy to get the water on to the land, it was difficult to get it off again. This entailed very late sowing with the consequence that practically all rain had ceased before it was possible to sow the crop and it had to be brought to maturity by such water as was left in the soil after visible water had disappeared.

In the winter of 1944–5 the possibility of controlling the water of the Abu Habl was again considered by an engineer and a more hopeful plan was produced than had been put forward previously. About the same time it became evident that the country was becoming very short of grain. It was accordingly decided to go ahead at once on an emergency basis with part of the new plan in order to obtain an extra 8,000 feddans of irrigated dura in 1945. This emergency project includes the erection of a regulator across the main khor in the neighbourhood of J. Daier, and a system of canals designed to irrigate land lying between the khor and the railway running parallel with it some miles to its north. Should the long-term plan for the utilization of the Abu Habl water materialize, this regulator will fit in with it. It will also carry the Rahad–Rashad road over the khor, which will be of immense benefit to communications during the rains.

Chapter XXX

DARFUR PROVINCE

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Senior Inspector of Agriculture[1]

General Remarks

Introduction

The following table shows the administrative arrangements:

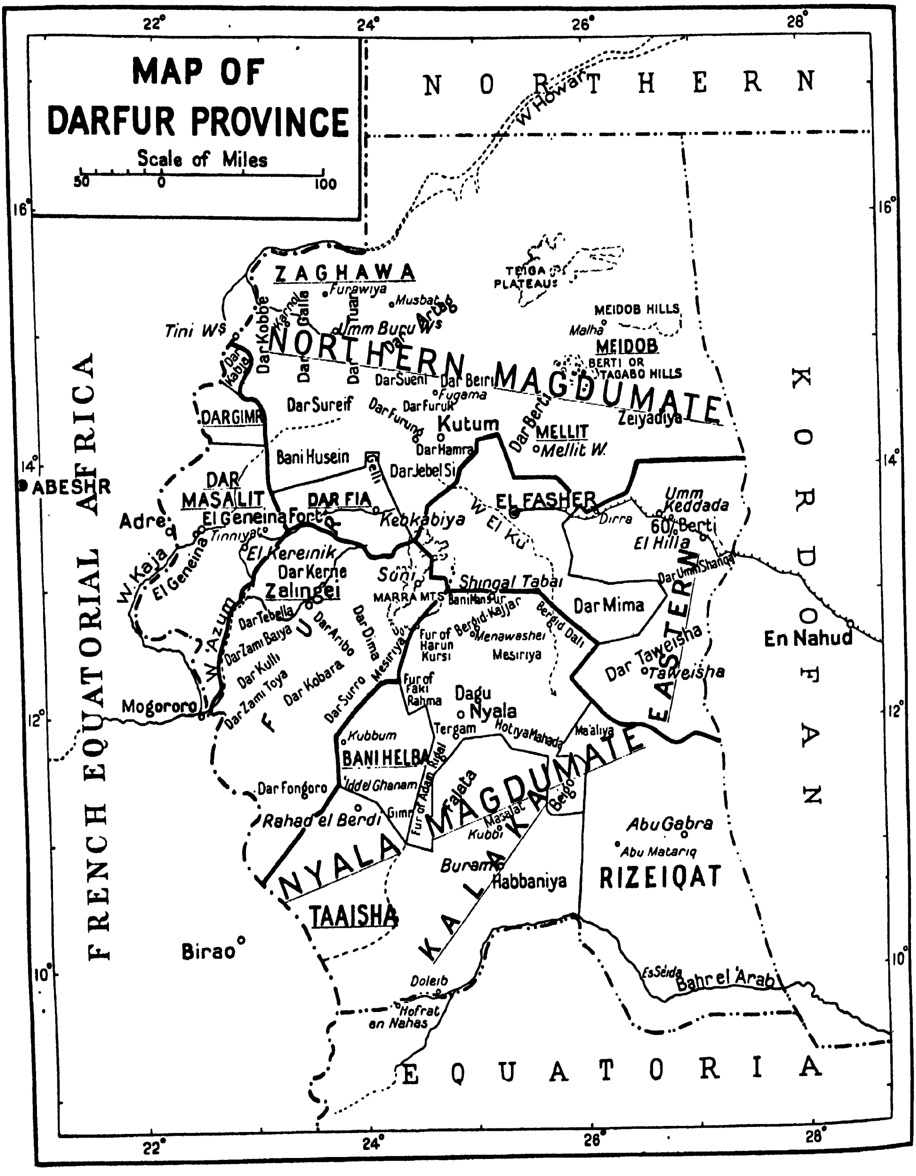
Province	*Chief town*	*Governor*
Darfur	*El Fasher* (Pop. approx. 18,000)	G. D. Lampen, Esq.

Districts showing Approximate Areas and Population and Government Stations

Districts	*Area (sq. miles)*	*Population*	*Government stations*
Dar Masalit	8,845	144,973	Geneina (District H.Q.)
El Fasher	18,290	95,807	El Fasher (District H.Q.)
			Um Kedada (Police post)
Northern	50,460	125,253	Kutum (District H.Q.)
			Kebkebia and Mellit (Police posts)
Southern	48,385	243,905	Nyala (District H.Q.)
			Buram (Police post)
Western	14,170	124,001	Zalingei (District H.Q.)
Total	138,150	733,939	..

Darfur is the westernmost province of the Anglo-Egyptian Sudan. It extends from about 10° N. to 16° N. and from 22° E. to 27° 30′ E., has an area of 138,150 square miles, and an estimated population of about 734,000. It is bounded north by the Libyan Desert, west by French Equatorial Africa, south by Equatoria and east by Kordofan Provinces. The last-named are provinces of the Anglo-Egyptian Sudan. The greater part of the country is a plateau from 2,000 to 3,000 feet above sea-level. A range of mountains of volcanic origin, Jebel Marra, runs north and south about the line of 24° E. and forms the watershed between the basins of the Nile and Lake Chad. About 70 miles long and 30 miles wide, its highest point attains nearly 10,000 ft. Eastward the mountains fall gradually into sandy, bush-covered steppes. North-east of Jebel Marra lies Jebel Meidob (highest point perhaps 5,000 ft.), a range much distorted by volcanic action, and Malha, an extinct volcano with a crater 300 ft. deep and 1 mile in diameter. South of Jebel Marra are broken tree-covered plains: south-west is a plateau which reaches a height of between 3,000 and 4,000 ft.

[1] In the preparation of this chapter the writer gratefully acknowledges generous assistance given by Messrs. G. D. Lampen and J. D. Tothill.—*R. T. P.*



MAP OF
DARFUR PROVINCE
Scale of Miles
50
0
100
22°
24°
26°
28°
16°
14°
12°
10°
NORTHERN
KORDOFAN
EQUATORIA
FRENCH EQUATORIAL AFRICA
ABESHR
ZAGHAWA
NORTHERN MAGDUMATE
EASTERN
MAGDUMATE
NYALA
KALAKA
TAAISHA
RIZEIQAT
MEIDOB
MEIDOB HILLS
BERTI OR TAGABO HILLS
TEIGA PLATEAU
W. Howar
Tini W.
Furawiya
Musbat
Umm Buru W.
Dar Kobbe
Dar Galla
Dar Tuar
Dar Artag
Dar Kabja
Dar Sueni
Dar Beiri
Fugama
Dar Furuk
Dar Sureif
Dar Furung
Kutum
Dar Hamra
DARGIMR
Bani Husein
Dar Jebel Si
Gelli
Dar Berti
MELLIT
Mellit W.
Zeiyadiya
Malha
DAR MASALIT
Adre
El Geneina
Fort
DAR FIA
Kebkabiya
EL FASHER
Dirra
Umm Keddada
Berti
El Hilla
Tinniyat
El Kereinik
Dar Kerne
Zalingei
Suni
Shingal Tabai
MARRA MTS
W. El Ku
W. Kaja
El Geneina
W. Azum
Dar Tebella
Dar Zami Baiya
Dar Kulli
Dar Zami Toya
Dar Kobara
Dar Aribo
Dar Dima
Dar Surro
Mesiriya
Bani Mansur
Berdid-Kajjar
Berdid Dali
Dar Mima
Dar Umm Shanqa
Fur of Berdid
Harun
Kursi
Menawashei
Mesiriya
Fur of Faki Rahma
Dagu
Nyala
Tergam
Hotiya Mahada
Ma'aliya
Dar Taweisha
Taweisha
En Nahud
Mogororo
FUR
Kubbum
BANI HELBA
Iddel Ghanam
Fur of Adam Rijal
Faleta
Dar Fongoro
Rahad el Berdi
Gimr
Masalat
Kubbi
Belgo
Abu Gabra
Abu Matariq
Buram
Habbaniya
Birao
Doleib
Hofrat en Nahas
Es Seida
Bahr el Arab

above the sea. The mountains are scored by numerous khors, whose lower courses across the table-land represent the beds of former rivers, now dry except when scoured by torrents in the rainy season. In the west and south, water can always be obtained in the dry season by digging 5 or 6 ft. below the surface of the khors.

The climate, except in the south, where the rains are heavy and the soil is a damp clay, is healthy except after the rains. The rainy season lasts from the middle of May to the middle of September. In the neighbourhood of the khors the vegetation is fairly rich.

In the north and east the chief trees are various acacias, *Balanites aegyptiaca* Del., and the Baobab (*Adansonia digitata* Linn.), hollowed out by the inhabitants in the sandy eastern area to serve as water-tanks. In the south and south-west the density and variety of trees are greater and includes *Cordia abyssinica* R. Br., yielding valuable timber, and mahogany. Cotton is indigenous and tobacco is grown. Bulrush millet (dukhn) is the staple food-crop, but wheat, dura, and other grains are grown. Other vegetable products are sesame, water-melons, onions, and tomatoes, while cattle-owning Baggāra produce large quantities of clarified butter ('semn').

There are deposits of copper at Hofrat el Nahas in the south-west and of rock salt in various places. Iron is also wrought in the south-west. Camels, cattle, horses, and sheep are numerous and of good breed.

Inhabitants

The population is very mixed. The negroid Fur (from whom the province takes its name) occupy Jebel Marra and the surrounding country. In the west are the Masalit, another non-Arab tribe who, like the Fur, speak a language of their own; and in the north are the Zaghawa and Meidob, probably Hamitic immigrants belonging to the Mediterranean or Brown race. The true Arabs are divided between the northern camel-owners and the southern cattle-owning sections. All are largely nomadic and move with their animals in search of water and grazing. In the east is the large negroid tribe of the Berti; and there are also remnants of the Dagu and the Tunjur, which were by tradition the early ruling houses of Darfur but were later driven out westwards by the Fur.

Slaves, ostrich feathers, gum, and ivory used to be the chief articles of trade, a caravan going annually by the 'arba'īn' ('Forty Days') road to Assiut in Egypt and taking back cloth, fire-arms, and other articles. Nowadays the chief exports to the east are cattle, sheep, camels, tobacco, hides and skins, gum, melon seeds, and semn. Much of the trade goes by lorry to rail-head at El Obeid, 4 days away, but camels are still extensively used. The principal imports are cotton goods, sugar, tea, and coffee.

The capital and administrative headquarters of the province is El Fasher (population about 18,000). It is some 350 miles west of El Obeid and 500 miles west-south-west of Khartoum. The province is divided into five districts with headquarters at El Fasher (central), Nyala (southern), Zalingei (western), Kutum (northern), and Geneina, the last named being also the headquarters of the Sultan of Dar Masalit. El Fasher and Geneina are airports on what was a main trans-African air route from 1941 to 1946.

History

The Dagu negroes, inhabitants of Jebel Marra, appear to have been the dominant race in Darfur in the earliest period of which we have any history. How long they ruled is uncertain, little being known of them save a list of kings. According to tradition the Dagu dynasty was displaced and Mohammedanism introduced about the fourteenth century by Tunjur Arabs, who reached Darfur by way of Bornu and Wadai. The first Tungur king was Ahmed-El-Ma'aqūr, who married the daughter of the last Dagu monarch. His great-grandson, the Sultan Dali, a celebrated figure in Darfur histories, was on his mother's side a Fur, and thus was effected a union between the Negro and Arab races. Dali divided the country into provinces and established a penal code, under the title of *Kitab Dali* or Dali's Book showing principles essentially different from those of the Koran. His grandson Suleiman (usually distinguished by Furian epithet Solong, the Arab or the Red) reigned from 1596 to 1637, and was a great warrior and a devoted Mohammedan. Suleiman's grandson, Ahmed Bahr (1682–1722), made Islam the religion of the State and increased the prosperity of the country by encouraging immigration from Bornu and Bagirmi. His rule extended east of the Nile as far as the banks of the Atbara. Under succeeding monarchs the country, involved in wars with Sennar and Wadai, declined in importance.

In 1799 Abd-er-Rahman, the then reigning Sultan, wrote to congratulate General Bonaparte on his defeat of the Mamelukes in Egypt. To this Bonaparte replied by asking the Sultan to send him by the next caravan 2,000 black slaves upwards of 16 years old, strong and vigorous. To Abd-er-Rahman likewise is due the present situation of El Fasher, the royal township. Previously the capitals of the Sultans had been in or near Jebel Marra, and the commercial capital until fairly recently was at Kobbe, about 50 miles north-west of El Fasher. Mohammed El Fadhl, his son, whose reign lasted till 1839, devoted himself largely to the subjection of the semi-independent Arab tribes who lived in the country. In 1821 he lost the province of Kordofan to the Egyptians. Of his forty sons, the third, Mohammed Hussein, was appointed his successor. In the later part of his reign Hussein became involved in trouble with the Arab slave-raiders who had seized the Bahr-el-Ghazal, looked upon by the Darfurians as their especial 'slave preserve'. The negroes of Bahr-el-Ghazal paid tribute of ivory and slaves to Darfur, and these were the chief objects of merchandise sold by the Darfurians to the Egyptian traders along the 'arba'īn' road to Assuit. Hussein died in 1873, blind and advanced in years, and the succession passed to his youngest son Ibrahim, who soon found himself engaged in a conflict with Zobeir, the chief of the Bahr-el-Ghazal slave-traders, and with an Egyptian force from Khartoum. The war resulted in the destruction of the kingdom. Ibrahim was slain in battle in the autumn of 1874, and his uncle Hassaballah, who sought to maintain the independence of his country, was captured in 1875 by the troops of the Khedive, and removed to Cairo with his family. The Darfurians were restive under Egyptian rule. Various revolts were suppressed, and in 1881 Slatin Bey (Sir Rudolf von Slatin) was made Governor

of the province. Slatin defended the province against the forces of the Mahdi, but was obliged to surrender (December 1883), and Darfur was incorporated in the Mahdi's dominions. Following the overthrow of the Khalifa at Omdurman in 1898 the new (Anglo-Egyptian) Sudan Government recognized (1899) Ali Dinar, a grandson of Mohammed-el-Fadhl, as Sultan of Darfur. A rising attempted by Ali Dinar in 1915 necessitated a punitive expedition in which he was killed (November 1916), and Darfur then became a province of the Sudan. Into it was incorporated the small, hitherto independent, State of Dar Masalit, which still enjoys a great measure of self-government under a Sultan, supported by a British Resident.

Present Administration

The administration at present is based on five districts, with the province headquarters at Fasher. Within these districts are over 60 tribes, Negroid, Hamitic, or Arab. Their independence has been modified by the formation of regional local governments embracing cognate or neighbouring tribes, each with their own judicial and limited financial powers. These regional administrations are now being consolidated into District Local Governments comprising the five districts, which will in time all have independent budgets. Dar Masalit Administration under a Sultan with his Council already comprises the whole administrative district based on Geneina. The Fur district of Zalingei also has its own administration and budget under a Magdum and Council of Chiefs. Northern and Southern Darfur are in process of welding their diverse tribal elements into a single council, and the Central and Eastern district will probably form a Rural Council with a town panel for Fasher.

A Province Council composed of representatives from all district local governments sits twice a year in El Fasher under the presidency of the Governor, and has nominated three of its members to sit in His Excellency's Advisory Council for the Northern Sudan.

Much of this local government machinery is still in the experimental stage, but the basic tribal local government is firmly founded on the rule of hereditary or traditional Nazirates or Sultanates, and they maintain public security, administer justice, collect taxes, and pay staff with little assistance from the Central Government authorities. They also, of course, administer the agelong tribal business of grazing, cultivation and watering rights, local trade and marketing, and control of cattle and human epidemics, &c.

The tribes group themselves roughly into the nomadic pastoral peoples and those who are sedentary and cultivate.

The nomads of the south are all cattle-owners. In the rains they range far north, to lat. 13°, and then as the water dries up they move south and west to their river grazing-lands on the Bahr el Arab, Kara, or Azum, where they remain till the rains and fly again drive them north.

The northern camel-owning tribes move in the same direction in the summer, but do not go to the extreme south. They haunt in these months the rich wadis round Jebel Marra, where they can find grazing, water, and grain.

The movement of trade is mainly local, and the large markets all over the country provide bartering centres between the sedentary and the nomad, where pastoral products are exchanged for grain and vegetables.

The nomads, in addition export their cattle on the hoof to Kordofan and their sheep to Omdurman markets in large numbers.

Export of other products out of the province is hampered by the long distance and bad state of the roads. Clarified butter, tobacco, and hides provide the bulk of the trade, and these move out by the Fasher–Nahud and the Abu Gabra–El Obeid roads. Within the province most transport is on animals. There are secondary motor-roads between all district headquarters and Fasher, and local roads out to big trading-centres, but motor transport is used mainly for the carriage of imported manufactured goods and the few commodities such as clarified butter and tobacco whose value can bear the cost of such transport. Other communications comprise an air line touching at Fasher and Geneina, and wireless communication to district headquarters, excepting Kutum.

Departmental activities in Darfur have been on the whole limited to medical and veterinary work, though some attention has been paid to horticulture. For agriculture and forestry the province has had to rely on occasional visits and reports.

General Description

Watersheds and Physical Features

The watersheds can be most conveniently divided into three groups:

Group 1. The largest. This begins slightly south and east of Jebel Hilla, runs north-west towards Kutum, west and north of Kutum, bends round to the south, thence passes almost due south, to include the Marra Mountains, to the southern boundary, dividing the province into two approximately equal halves.

Group 2. (*a*) Begins in Group 1 between Kutum and Mellit, passing north-east to the province boundary, and includes the Tagabo Hills.

(*b*) Just north of Kutum a long group of hills stretches almost due north in the form of a gigantic spur from Group 1.

(*c*) Similarly a second elongated spur juts out from Group 1 from slightly north of Kutum in a north-westerly direction towards Tini Wells.

Group 3. A group of mountains near the north-west boundary of the province, but in French Equatoria, is included here as from it rises the important Wadi Howar which runs north-east through the north-western corner of the province into Northern Province.

From these watersheds drain three principal rivers or wadis:

Wadi Howar in the north-west.

Wadi Ku east and south from Group 1.

Wadi Azum west and south from Group 1.

All secondary wadis of any importance drain ultimately into one or other of these three principal wadis or directly into the Bahr el Arab or its extensive system of marshes.

Wadi Howar is a seasonal river flowing into and disappearing in the

FIG. 340. From the top of Jebel Marra looking along the crater rim and slightly down at Jebel Kurunga. Note the absence of forest (*photo J. D. Tothill*).

sandy wastes of the north. Wadi Ku is also seasonal and disappears in a desert delta in the semi-arid area east of Nyala; many of its would-be tributaries also terminate in desert deltas. The Wadi Azum is likewise seasonal and flows into French Equatoria forming part of the Lake Chad drainage system, but whether its waters now reach the lake is not known to the writer. Many, perhaps most, of the cultivating communities are based on these wadis or their tributaries whose banks they cultivate, and whose sandy hinterlands provide the main grain areas. They are the main source of drinking-water and are therefore economically one of the principal features of the province. Of the three wadis, Azum is the largest, longest, and carries the greatest amount of water; its banks are more densely populated and intensively cultivated than either of the other two principal wadis.

The Bahr el Arab runs west to east approximately along the southern boundary of the province. This river never completely dries up, and pool water in the dry season is always readily available. The relatively dense population squatting along its banks in the upper reaches enjoys a rural economy peculiarly its own.

Characteristics of the Main Areas

The extreme north is a mixture mainly of sandy desert and stony wastes, and provides a meagre and precarious livelihood for a very sparse populace. The central and southern sections of the north are rather less unkindly; cattle, camels, sheep, and goats exist in some numbers. Grazing is less unreliable, and, in the southern section especially, considerable areas are under cultivation.

Although much of the central and southern belts consists of uninhabited scrub owing to the lack of drinking-water, grazing is more reliable, and there is more evidence of cultivation; cattle, sheep, and goat herds are numerous, and horse-breeding is of local importance.

Along the upper reaches of the Bahr el Arab true squatting occurs on the banks of this river. Drinking-water is available throughout the year; good river silt land is available for crops; and grazing for cattle, sheep, and goats is available on the higher lands. In this comparatively small area an apparently happy and contented sedentary population has developed.

Generally speaking, however, the Bahr el Arab lands are marshy and are used by the Baggāra Arabs as a summer grazing-land for their cattle.

Too little has been told of the truly glorious Jebel Marra region. From the cool heights to the fertile foot-hills it gives the stranger food for much reflection and causes not a little wonder. The main high-level water channels, leading from perennial streams which may be as much as a mile long, are brought in places round the shoulders of hills—no mean engineering feat—to the cultivations. No intricate levelling instruments are employed: the levelling is all done by eye and done perfectly. Terraces, massively built of enormous boulders, rise tier upon tier to the very crowns of some of the highest peaks: they are a testimony to prehistoric man's energy and, by present-day standards, incredible physique. The modern Hill Fur, with his smaller water-supply, has followed, in no mean fashion,

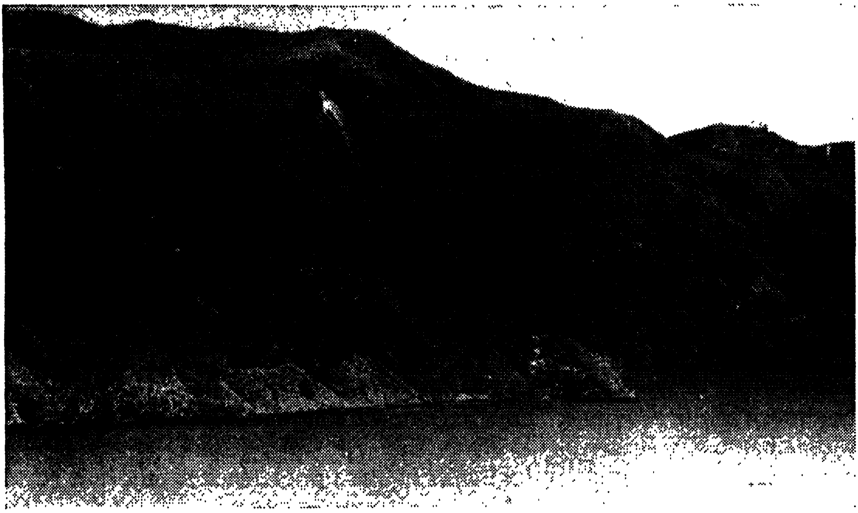


FIG. 341. The smaller of the two crater lakes of Jebel Marra. The excellent preservation of the crateral wall suggests that this is where the final activity of the volcano took place and that this is the source of the pumice and volcanic dust that form the weak rock now being carved into bad lands and transported to the valleys below (*photo J. D. Tothill*).

FIG. 342. The larger lake of the J. Marra crater is as salt as the Dead Sea. Note the salt deposit on the beach. The crater wall behind shows the grass and herbaceous type of vegetation characteristic for the upper three thousand feet (*photo J. D. Tothill*).

the example of his muscular predecessor. The exemplary neatness of his relatively minute river-valley terraces, the cleanliness and care he takes of his more extensive hill terraces, testify to his energy and, generally, sound cultivating principles.

Soils

Continental Sands or 'Qōz'.
Silts.
Clays.
Volcanic deposits.

Continental Sand or 'Qōz'

The most important agricultural soil in Darfur consists of the vast area of now static billowy sand that spreads over much of the province with tongues running southward on both sides of Jebel Marra.[1] In pure form it is characteristically free from mica and is thought to be derived from the disintegration of the Nubian Sandstone that lies everywhere to the north and north-east, and to have been deposited or redeposited by the trade winds as desert sand in the final dry period of Pleistocene times. It is a soil of low fertility, but preserves for the use of crops practically all the rain that falls.

Silts

These are recent deposits and have been laid down generally only to a narrow depth along the banks of all rivers and wadis. The silts are the most fertile of all Darfur soils. They are particularly suited to the successful culture of tobacco, vegetables, and fruits. Where silts occur extensively in areas of suitable rainfall as, for instance, along the Wadi Azum valley, heavy grain (dura) crops are also obtained (see Fig. 344).

Clays

There are extensive deposits of alluvial clay in all the riverain lands of Darfur. They are thought to be Pleistocene in age, but at no place have they as yet been closely dated. Agriculturally they are unimportant because the rainfall is inadequate for the growing of crops upon them. In the extreme south the clay marshes of the Bahr el Arab provide summer grazing for the cattle of the Baggāra tribe.

The clays seem to have been deposited at more than one period in Glacial times because two major clay terraces are exposed along many of the rivers; and in a 10-ft. deep soil pit, situated towards the head-waters of the Wadi Orra, 1 mile west of Kebkebiya, there is a suggestion that clays may have been deposited at four separate periods of time. In this pit the succession is as follows:

Foot 1. Recent deposits of finely bedded silts and sands.
,, 2 and 3. Hard clay with fairly well-defined cracking system showing mottling due to carbon remains.

[1] In Darfur generally the desert sand is not creeping southward, but active dunes are beginning to form in the periphery of towns and villages. See Report of Soil Conservation Committee, 1944.—*Editor.*

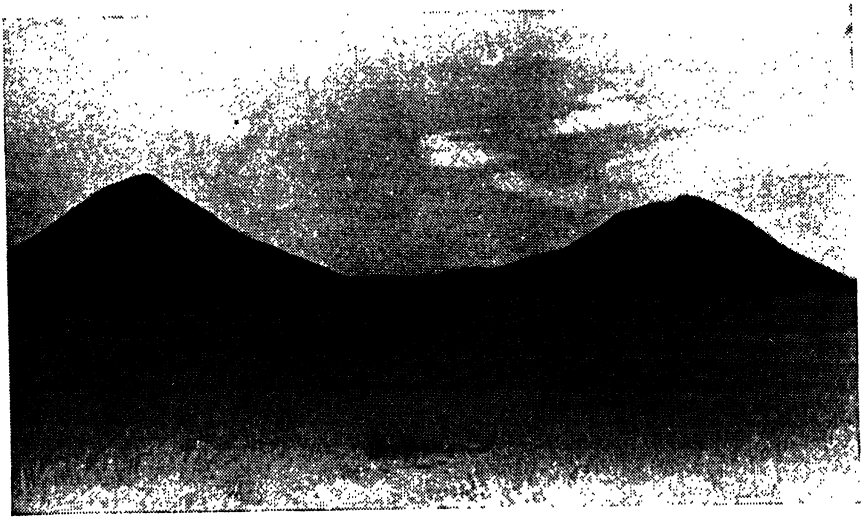


FIG. 343. Continental sand with an almost pure stand of 'haskanīt' now buries this old volcanic crater of J. Toma at 14° 30′ N. as seen from J. Kurgoa. It characteristically buries the lower slopes of all hills in its path. It is now anchored and forms no active dunes (*photo J. D. Tothill*).

FIG. 344. Recent silts at right deposited on continental sand at left a stone's throw from the brick kiln at El Fasher. The silts are full of animal bones and pottery fragments. The author standing near the sloping junction of the two deposits (*photo J. D. Tothill*).

FIG. 345. Nubian sandstone outcrops occur over much of northern and north-eastern Darfur. This is thought to be the source of the continental sand or 'qōz' of Darfur and Kordofan Provinces. Photo taken 2 miles east of Abiad on the road to Nahud. Note the much darker ferricrete layer on top (*photo J. D. Tothill*).

FIG. 346. Cracking clay and desert 'qōz' occur widely over Darfur Province. The clay in this photo represents the upper terrace of the Barai river system. The sharp line of demarcation is characteristic (*photo J. D. Tothill*).

Foot 4. Gravel grit and sharply angular micaceous sand.
Pottery sherd at base of this layer.
Foot 5. Hard clay with thin beds of granitic sand and mottled with bog-iron stains.
↓ Angular shárp granitic sand.
Tough clay stained with bog iron.
↓ Coarse angular sand.
Foot 10. Hard clay.

Volcanic Deposits

Agriculturally volcanic deposits are confined almost exclusively to the Marra Mountains and the central range running northwards and ending slightly east and north of Kutum. Much smaller groups of basalt hills occur near Mellit, also at the Tabago Hills, and a third and last minor group occurs approximately half-way between Mellit and the northern boundary, but these are agriculturally unimportant due to lack of rainfall.

In the Marra Mountains the soil is derived mainly from the breaking down of a weak rock (Fig. 347) formed of tuff or volcanic dust, but some of the soils are formed from basalts. Pumice occurs at many places. The recent silts of the terraces and desert deltas of the streams flowing eastward from Jebel Marra are largely composed of this volcanic material and owe to it their fertility. The gardens at Suni and Kalokitting and the tobacco lands at Shingal Tubai are examples.

Relative Temperatures

General

Most of the southern district is hot. The Marra Mountains and Zalengei area of the southern district and the remainder of the province are, compared with the easterly provinces, relatively and pleasantly cool. Much of the province is high, for example, Jebel Marra is slightly under 10,000 ft. above sea-level, the aerodrome at Fasher 2,700 ft., and Kutum over 4,000 ft. This is, without doubt, the most pleasant, since the least trying to live in, of all provinces of the Sudan. The economic and agricultural significance of a relatively low temperature to a province having, in over three-quarters of its area, an uncertain and unreliable rainfall, needs no emphasis.

Average Rainfall Statistics

Darfur

1918–40 inclusive

	May	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Yearly mm.*	*Total average (inches)*
Fasher	10	17	109	134	34	5	309	12·165
Nyala	37	69	130	171	95	19	521	20·512
1932–40 inclusive								
Kutum	10	14	113	159	47	2	345	13·582
Zalingei	34	67	180	226	88	17	612	24·098
Geneina	24	47	167	228	69	5	540	21·417

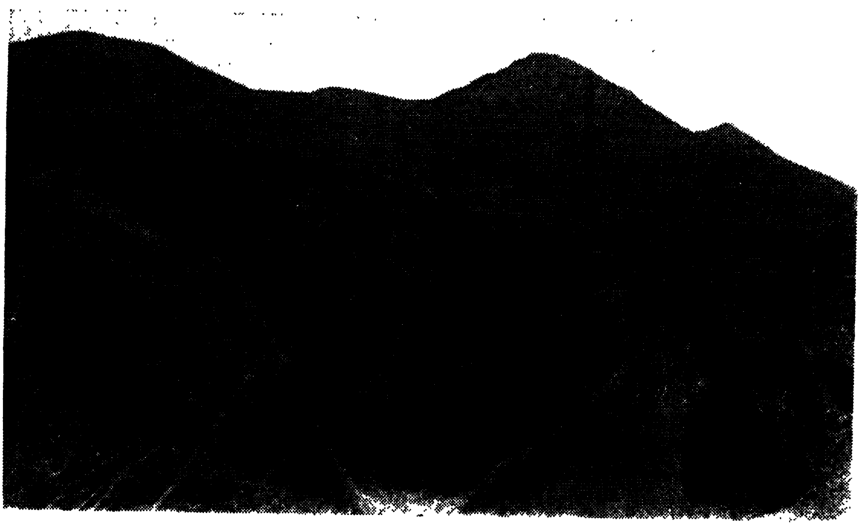


FIG. 347. On the path from Koranga to Fantanga are bad lands carved by water from a weak rock composed of successive deposits of volcanic dust or tuffs. These are being redeposited at places like Shingal Tabai as good agricultural soils (*photo J. D. Tothill*).

FIG. 348. A valley in the bad lands of Jebel Marra on the path from Koranga to Fantanga. There is no forest at this altitude of 7,000–8,000 ft. An occasional *Euphorbia candelabrum* Trém., *Acacia albida* Del. occurring as a bushy tree, and a few scattered graceful *Olea chrysophylla* Lam. occur (*photo J. D. Tothill*).

With regard to Jebel Marra Mountains and vicinity, rainfall on the west side is probably 30 in. or more and there is little danger of drought despite rapid run-off due to steep sloping land. On the east side of the range rainfall is distinctly lower; loss of crops from drought is liable to occur oftener.

Regarding the province as a whole, and from the point of view of crop security, the province can be divided arbitrarily into two main sections, with the Marra Mountains forming a subsidiary but none the less important third section. The 500-mm. isohyet runs from north of Geneina and Zalingei to include Marra Mountains, east and south to a point near Nyala, thence swings almost due east to the province boundary.

North of the 500-mm. Isohyet

This area occupies roughly two-thirds of the province and extends north of the 500-mm. isohyet to the desert and the frontier. It includes lands that have a 'nearly but not quite good enough' rainfall for crops and a great area where rain agriculture is out of the question. Cultivation of rain lands within this area generally yields a precarious livelihood; but cultivation of riverain silt lands, where a river supplies part of the moisture, is generally quite good. The light rainfall is, however, fully conserved on the extensive 'qōz' lands, which produce abundant fodder for camels far into the north, and over great areas excellent grazing for cattle. The area is largely occupied by nomad Arab tribes owning camels or cattle.

South of the 500-mm. Isohyet

In this area, comprising approximately one-third of the province, the rainfall varies from 500 mm. in the north to 700 mm. in the south, with, in the extreme south-east, a small, very small, area with 800 mm. and over of rain.

In this belt there are real possibilities of systematic agricultural development. With a much heavier and more reliable rainfall, and a denser population, the same risk of failure and disappointment does not exist. Much has been, and is being done, by the administration to develop this area, and considerable advances have been made.

Marra Mountains and Vicinity

A heavier rainfall spread over a longer period annually and the existence of perennial streams have imparted to this area a distinctive agricultural economy.

VEGETATION

The vegetation map of the Sudan prepared by F. W. Andrews at p. 34 shows that Darfur Province consists in the extreme north of desert; to the south of this of a belt of 'acacia desert scrub'; to the south of this, with El Fasher on the boundary line, of a somewhat narrower belt of 'acacia short grass scrub' the southern boundary of which curves round the north of the Jebel Marra range; then to the Bahr el Arab of a broad

belt of 'acacia tall grass forest'; while out of this latter belt rises the Jebel Marra uplift with a dry mountain flora above 5,000 ft. with a climate suited to rain-grown wheat.

The flora of these several zones is described by F. W. Andrews, but may be slightly amplified in respect of Jebel Marra and of 'gizu'.

The dominant but scarce tree above the level of the crateral floor of Jebel Marra is the golden-leaved olive of the Red Sea Hills *Olea chryso-*

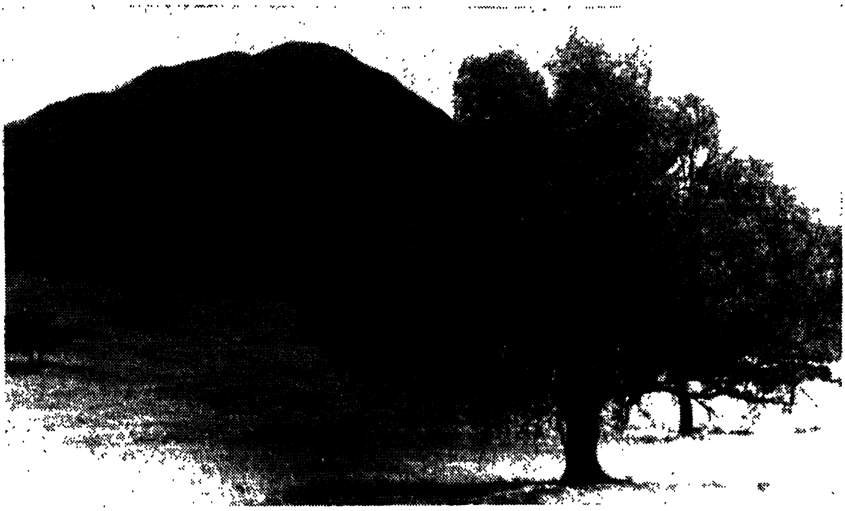


FIG. 349. The golden-leaved Olive is a characteristic and graceful tree of the Jebel Marra crater area. The heavy squat tree at left is *Acacia albida* Del., also characteristic. These are the only trees that grow albeit as dwarfs within 1,000 ft. of the top of the mountain. There is, however, no forest (*photo J. D. Tothill*).

phylla Lam., although *Acacia albida* Del. occurs as a smallish tree in the crater and as an even smaller bush up to about 1,000 ft. from the summit. A *Rhus* and a rough-leaved fig, *Ficus palmata* Forsk., also occur at the crater level. Above this level on the crateral walls the herbaceous heather *Blaeria spicata* Hochst. is in places common. Below the level of the crater floor and above the level of the 'acacia tall grass forest' a number of plants occur such as *Erythrina* sp., *Phoenix reclinata* Jacq., *Carissa edulis* Vahl., *Ximenia americana* Linn., all of which indicate considerable rainfall without great extreme of heat or cold.

'Gizu' is referred to in the chapters on animal foodstuffs and Kordofan (pp. 670 and 830) and is a collective term used by nomad Arabs to describe fodder plants that provide both food and moisture for grazing animals and that grow on the fringes of the northern desert. In Darfur these plants are naturally of particular interest. One of these plants, local name 'derma', grows luxuriantly in patches in the cracking clay bed of Wadi Howar north-west of Um Buru and 20 miles north of Boba. This area is waterless for some months, but 'derma' (an *Indigofera* probably *linifolia*) in May is sufficiently luxuriant in patches to maintain goats in good condition and in milk with no drinking-water whatever.

A word may also be added about the grazing grass 'haskanīt', *Cenchrus biflorus* Roxb., probably the most widely spread of all grasses on the continental sands of Darfur Province. The bristles, which are semi-rigid and copious, stick into stockings, shirts, pants, and legs, particularly if the latter are bare and hairy, cause intense irritation, and constitute one of the 'white man's burdens'. This annual grass although rather coarse is readily eaten by animals and persists plentifully in the dry season.

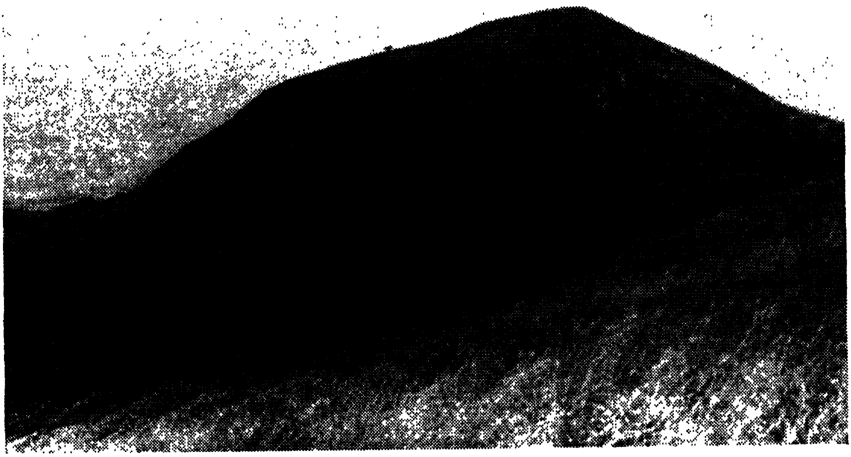


FIG. 350. Photo from the actual top of Jebel Marra with camera tilted down on the crater rim. The vegetation consists of grasses and herbs and there is a notable absence of trees. The bush on the sky-line is a dwarfed *Acacia albida* Del. (*photo J. D. Tothill*).

AGRICULTURE BY TRIBAL AREAS

As already stated, the population of Darfur is very mixed. For the purpose of this article, however, it may be divided into nomad Arabs, the Furs of Jebel Marra, the Masalit of the Geneina area, and the Fellata immigrants.

The Nomad Arabs

The Arabs are to be found in all walks of life and are ubiquitous. In the north they are nomadic, elsewhere they are mostly semi-nomadic. Quite a large number are cultivators. They are also to be found as tradesmen, policemen, clerks, storekeepers, &c. They are noted horse-breeders and own many herds of camels, cattle, sheep, and goats.

In the north the nomads are primarily camel-owners and depend on the camel to a great extent for their existence. The camels feed largely on 'sallam' (*Acacia flava* (Forsk.) Schweinf.), 'seyal' (*Acacia raddiana* Savi), and 'samr' (*Acacia tortilis* (Forsk.) Christensen), all of which occur in the 'desert scrub' flora region fringing the desert. The plants collectively known as 'gizu' are also important in the same area. Annual migrations to the south take place, however, as routine, with the western

FIG. 351. Recent erosion of weak rock formed of volcanic dust into bad lands. On the path from Koranga village to the Jebel Marra crater. The bedding of the tuff shows clearly at top right (*photo J. D. Tothill*).

Fig. 352. Terraced hill-sides above Suni. These remarkable terraces protect most of Jebel Marra from erosion and go to within 1,000 ft. of the mountain top. They are used for rain-grown crops (*photo J. D. Tothill*).

Fig. 353. Terraces now in use at Suni. They are faced here with rows of basalt stones. In places they are faced with quite well-built stone walls 3–4 ft. high (*photo J. D. Tothill*).

wadis of Jebel Marra being one of the main objectives as there is grazing for the camels and grain to be purchased.

The camels are used largely for transport purposes, and carrier contracts are normally arranged annually for the carrying of produce and of trade goods over wide areas in the central and northern Sudan.

The food of the northern nomads consists largely of milk and meat from camels, goats, and sheep; and of dukhn grain (*Pennisetum typhoides* (Burm.) Stapf and Hubbard).

Dukhn or bulrush millet is eminently suited to the 'qōz' lands, requires less rainfall than dura, and fewer man-hours of labour. Tea, coffee, sugar, and dura are also used to a considerable extent and these are purchased.

The southern nomads are cattle- rather than camel-owners and depend largely on cattle for their existence. In the rains they range as far north as the thirteenth parallel of latitude and then return to their river grazing-lands on the Bahr el Arab, Kara, or Azum.

The diet of these Arabs is similar to that of the northern nomads except that milk and some meat are supplied by cattle instead of camels.

The Fur of Jebel Marra

In fact there is no rigid distinction, but as the cropping systems vary it is convenient in this discussion to divide them into the Jebel Marra or Hill Fur and the Lowland Fur.

The Hill Fur

These are the true mountain people who live, hunt, and cultivate above the 4,500-ft. level. They keep some cattle and a few goats and sheep. They are the most industrious cultivators in Darfur, and all their crops are grown on the great system of terraces that almost completely cover the surface of the mountain almost to the 9,000-ft. level.

Most of the crops are grown in the rains, but for short distances there is permanent water in many of the mountain valleys and in these valleys the inhabitants grow crops in the dry season under irrigation on what is frequently a superbly designed series of minute terraces.

Wheat is grown in summer as a rain, and in winter and spring as an irrigated, crop.

'Bamia' or okra and sweet potatoes are also common on the irrigated lands, while tomatoes, onions, carrots, and other vegetables add variety to the diet.

Village Survey at Furjili on Wad Jawa at 13° 03′ N., 23° 21′ E.

A few days were spent at this small but typical village a few miles below Suni doing a survey to find out something about the agricultural habits and way of life of the Hill Fur, and the following notes are from the record. Three cultivator households were selected as being typical, one being well off, one medium, and one poorish according to local standards.

The Family. The large-scale cultivator had 4 wives, 2 sons, 2 daughters, and 3 nephews, and all but the youngest three children normally helped

in all phases of cultivation. The next family consisted of husband, wife, son, and daughter, all of whom helped with the cultivation. In the last family there were husband, wife, daughter, and mother all working.

The House. In all cases huts were of the round type with stone walls and thatched roof and were maintained in excellent order. They were situated on well-drained land close to a running brook, and the custom was for each wife to have a separate hut.

Daily Habits in regard to Food. Two meals a day is the custom, 9 a.m. and at sunset. The basis of both meals is a sort of porridge called 'asīda',

FIG. 354. Pollarded trees and terraced irrigated cultivation at Suni, Darfur. 6,000 ft. (*photo E. H. Nightingale*).

prepared from wheat or dukhn or both. To this is added a sauce that may be made (*a*) of pounded dried meat mixed with cayenne pepper, salt, and 'bamia'; (*b*) fresh meat cut small, cooked with onions, semn, pepper, and salt; (*c*) young growth of 'melukhiya', cooked with salt; (*d*) 'kowal'. In this latter case the product is prepared and stored dry. The luscious green plant *Cleome viscosa* Linn. is obtainable only in the rains; it is pulled green and pounded in a mortar or 'fundūq', placed in an earthenware jar or 'burma', covered with leaves of *Cordia abyssinica* R.Br., and buried in earth up to the neck for a month to ferment. The mass is then extracted, being dried out in small heaps or lumps the size of a large chestnut. Two or three of the lumps may be used at a time as flavouring in cooking. In addition to these normal sauces powdered bones may be used; in this case fresh bones are ground to powder and kept for a day or two to acquire flavour. Also buttermilk, from the plains markets, mixed with native pepper, salt, and 'bamia' is sometimes used. Sugar is scarcely known, the monthly allocation for 2,000 people being 60 rotls. All tribesmen are, however, fond of native bees' honey and use it freely with dukhn or wheaten bread called

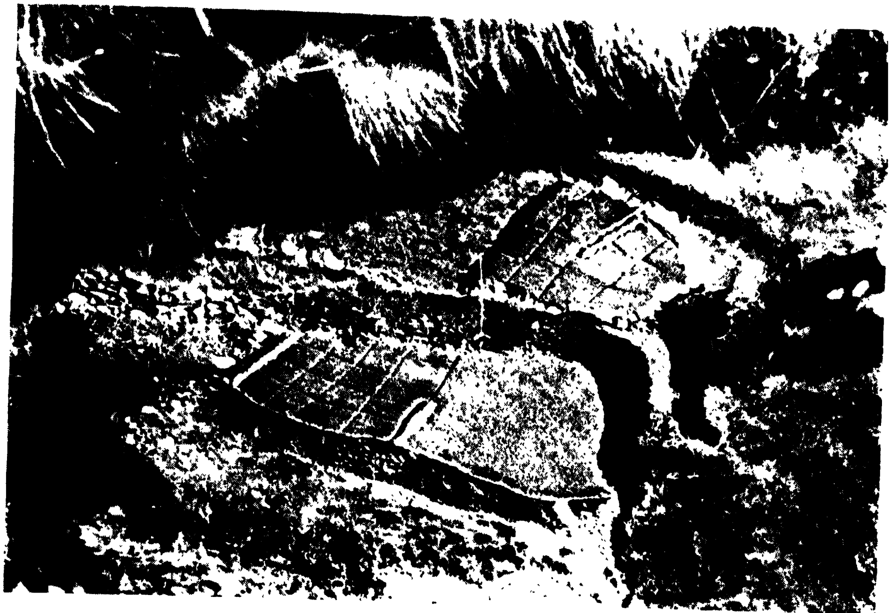


FIG. 355. Terracing and irrigation at Fantanga on the path from Jebel Marra crater to Suni. The brook has permanent water from a point just above this garden. The neatness of some of this high-level terracing is remarkable (*photo J. D. Tothill*).

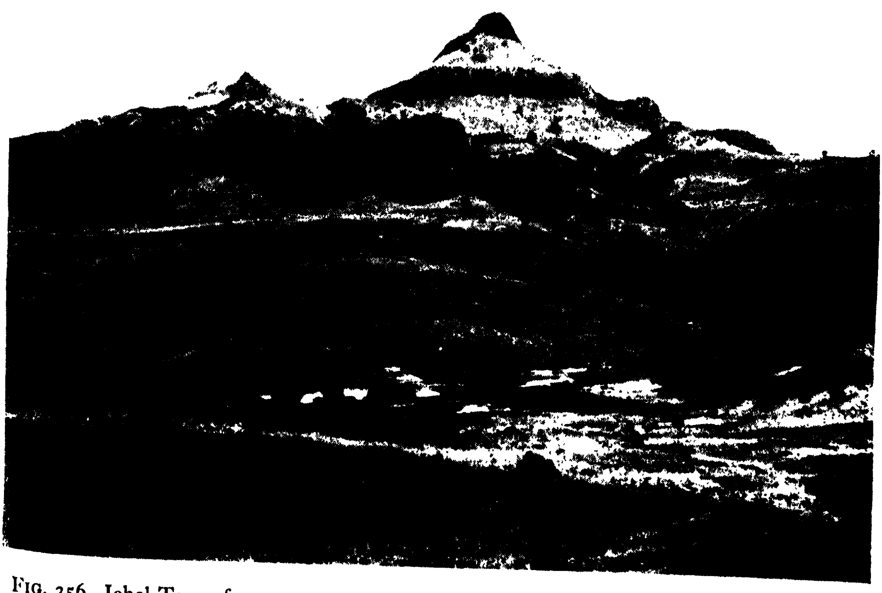


FIG. 356. Jebel Toum from our camp in Wadi Dulero on the path from Jebel Marra crater to Suni. Taken in May. The pale patches are ripening wheat watered by irrigation. Wheat is one of the main crops at this elevation and is in all stages (*photo J. D. Tothill*).

'kisra'. Tea and coffee are scarcely known, the national drinks being water and native beer; milk is used as a luxury drink by adults and young alike and is used with 'asīda', but is not plentiful.

Clothing. The basis of clothing material is native spun and woven cotton cloth called 'damūr', both the cotton and the industry being indigenous. The men wear the Arab 'libās' or baggy trousers, and the 'gibba', a loose-fitting shirt-like outer garment. The women wear a 'tōb' wound gracefully round the body. The very young of both sexes go naked. Imported

FIG. 357. A Fur family sowing wheat in the Nyuringa valley of J. Marra at about 7,000 ft., Nov. 1940 (*photo E. H. Nightingale*).

cotton-piece goods were in small but increasing demand prior to the second world war. The people of the survey were adequately clothed.

Household Effects. In the case of the large-scale cultivator the hut of the first wife contained:

14 'burām' or fired earthenware pots, assorted.
5 'tabaq' or plaited grass covers.
2 'reika' or large strong receptacles of plaited fibre.
1 'qadah' or wooden bowl—*Sclerocarya* wood.
7 'kas'. A 'kas' is a gourd container for water, meal, &c.
2 'murhāka' or stones for grinding wheat or dukhn, 1 coarse, 1 fine.
1 large mud receptacle for storing grain.
2 carrying nets for transport of goods to market by animal.
1 'angarib' or native bed of plaited rope on a wooden frame supported on four stout legs.
1 stool.
1 small brass tray.
1 metal cooking-pot.
1 tea pot.
1 long string of beads.
8 pigeons.

The huts of the other wives contained similar items but fewer of them.

In the case of the medium-scale and small cultivators the household effects were of the same type as those listed above, but 'burām' and 'kas' were reduced in numbers.

Livestock. The large-scale cultivator owned 2 cows, 6 female goats, 2 male goats, 1 donkey, and 1 camel.

The other two families possessed no animals.

Forage and Grazing. The domestic animals receive no grain and feed on hill-side grasses and herbs and on 'qassab' or the stalks of dukhn and

FIG. 358. Fur people threshing wheat on Jebel Marra in the Suni valley at about 6,500 ft. in May 1939 (*photo E. H. Nightingale*).

wheat. There is a green bite during the rains, and very small quantities of green food may be available in the dry season along the fringes of perennial streams and winter irrigations. 'Qassab' is hand fed in the cattle 'zarāib' or pens.

Milk Supply. Only one of the families investigated possessed any milking animals. Milk in this area is scarce, due to lack of grazing, and children generally are weaned very gradually on to 'asīda' and native beer.

In other tribes where grazing is more plentiful there are more cattle, sheep, and goats and the people drink more milk and eat more meat.

In all cases milking is done in the morning prior to turning the animals out to graze and in the evening after return to the 'zarība' (there are lions and leopards on the mountain and animals have to be protected at night).

Land and Crops. The right to the use of land is inherited, and all men of this village have the use of some 'kharif' terrace land and most to the use of a small area of irrigation land. In the absence of an occupier someone else may work the land, but a son of the original occupier may claim the

FIG. 359. In remote parts of Africa salt is often a problem. The Jebel Marra folk obtain theirs locally by collecting and washing the salty earth from the salt-works shown. The works are about 1,000 ft. below the camera, the salt oozing out from the base of the hill (*photo J. D. Tothill*).

FIG. 360. The only mature date-palms in Darfur Province are at Kuttum where they have bee planted in the recent silt of a river valley. The rock here is granite and there is a goo deal of continental sand (*photo J. D. Tothill*).

right to work the land after the crops of the intermediary have been duly harvested.

In the case of the large cultivator the land and cropping were as follows:

'Kharif' (rains only) terrace land.

20 feddans. Yield 20 ardebs of 336 rotls or approximately 3 tons of grain.

Permanent irrigation. Crops as at April.

50 sq. yds. onions.
340 ,, potatoes.
180 ,, fruit, i.e. 5 orange, 1 grape-fruit, 1 fig, 1 banana, 1 guava.

FIG. 361. A cluster of grape-fruit in the Suni experimental garden. This is tree S. 5 planted in 1937. The quality is excellent (*photo J. D. Tothill in May 1943*).

In the case of the medium-area family crops were:

Kharif terrace land.

5½ feddans of dukhn. Yield 6 ardebs or just under a ton of grain.

Permanent irrigation.

560 sq. yds. potatoes.
100 ,, turnips.
195 ,, carrots.
38 ,, maize.
20 ,, 'lubia'.
24 ,, strawberries.
10 ,, tomatoes.
15 ,, cassava.
300 ,, fruit, e.g. 1 lime, 5 oranges, 1 Yusef effendi, 1 grape-fruit, 1 maltese lime, 8 bananas, 9 guavas, 4 mulberries, 5 papaws, 3 figs, 2 mangoes.

The smallest area family had 3 feddans of 'kharif' dukhn yielding 3 ardebs or rather less than half a ton of grain; and under permanent irrigation 65 sq. yards of potatoes and 50 of onions. The man works as

a chief's messenger, and his rations are brought up to a good maintenance level in return for this service.

Financial Position and General Well-being. The largest cultivator estimates that he requires £E.60.000[1] annually for taxes, clothes, and entertainment. This family is living well on a varied diet on the fruits of its labour and is steadily accumulating property. The head of the family says that peace and security have brought the conviction that whatever a man harvests will surely be his own and that the tendency is therefore to work more land and to acquire additional possessions. He says he is better off than 10 years ago.

FIG. 362. The Fur people have learned to use water wisely. Here is an aqueduct across a stream in the J. Marra area at about 4,000 ft. (*photo E. H. Nightingale*).

The financial requirements of the middle-size family are £E.15.000 annually for taxes, clothing, and entertainment. The head of the house says he is better off than 10 years ago and for the same reasons as given above.

The smallest unit requires £E.10.000 annually and claims to be better off than 10 years ago for reasons as given above.

Summary for Jebel Marra Fur. The survey applies in detail only to the 2,000 people of the tribe in question. As one ascends the mountain more wheat and less fruit are grown. Animal population and milk supplies vary with available grazing. On the whole the Jebel population is well fed, contented, and becoming increasingly prosperous—on an almost self-contained basis.

[1] Probably too high an estimate.—*Editor.*

The Lowland Fur of Zalingei

The Zalingei district lies south of the desert 'qōz', and its agriculture is based on rain cultivation of riverain lands. These lands are very extensive and characteristically have a layer of recent silts, derived from micaceous rocks, overlying pervious clay. At Zalingei station a soil pit showed 18 in. of silt over 8·5 ft. of stiffish clay mottled with bog-iron staining and with a band of river sand in the 8th foot. The clay becomes moist in the 6th foot and moisture increases with depth. In the near-by garden wells the water stands at 15 ft.; under it is gravel, and under the gravel the basement complex rock of the area.

These lands are characterized by great trees of *Acacia albida* Del. or 'harāz' and to a smaller extent by large trees of *Acacia campylacantha* Hochst ex A. Rich. This general growth of extremely well-grown trees indicates that ground water is available throughout the year.

In the rains dukhn is grown on these lands as the main grain crop; dura is grown to a smaller extent. Simsim is important. Under kharif conditions the common vegetables are grown, particularly tomatoes, onions, sweet and increasingly English potatoes, fenugreek, fennel, coriander, capsicum, peppers, okra, and earth-nuts.

A few plots of vegetables are also grown under irrigation from wells, but well water is strictly limited, and most of it is required for human consumption and for stock.

Cattle, sheep, and goats are kept to a somewhat limited extent.

Cotton is grown for local spinning and weaving.

The Masalit of Geneina

The origin of this tribe is uncertain, but it is non-Arab and non-Fur. It is an agricultural sedentary tribe possessing limited numbers of cattle, sheep, and goats, growing much the same crops as the Fur of Zalingei. The main agricultural difference is that the 'qōz' sand covers much of Geneina, and that crops are grown on 'qōz' as well as in riverain lands. Dukhn is the main grain crop, and ground-nuts tend to replace simsim.

Other Areas

In other areas on the plains agricultural tribes have to contend with lighter rainfall and a more precarious existence. In these areas dukhn grown in the rains on the 'qōz' is the basic food-crop. Little patches of cotton are also commonly grown for local spinning and weaving. Riverain agriculture on recent silts is also normal practice in appropriate areas.

This account would be incomplete without some reference to the tobacco industry of Shingal Tubai.

The area is a desert delta of deep volcanic silt from Jebel Marra that retains its moisture for many months after the floods have ceased.

Sowing is done as soon as all food-crops have been established. It is done by broadcasting on land first cleared of weeds, and the plants are thinned to 1 metre between rows and ½ metre between plants in the rows. A second and sometimes a third weeding is necessary. Pruning is confined to destroying root-suckers and to breaking off fruiting-tips until

leaf-picking is finished, when the tips are allowed to remain in order to secure a seed-supply for the following year.

Leaf-picking begins when the plants are about 5 months old and continues for 2 months.

The leaves, picked green, are built up into small circular heaps, locally 'subra', under shade. They remain in these for 7 to 10 days until they turn yellow.

The yellow leaves are then stacked for curing into large 'subra' with tip and base of leaves directed alternately to centre of stack. The large heaps may be torn down and remade to secure evenness of product.

When the leaves are cured to a brown colour and the stems have dried out the tobacco is packed in 'bursh' or matting containers for animal transport to market. It may have to be moistened for packing if it has become brittle.

Although tobacco originally came to Africa from America, the Darfur industry has been in existence for a number of generations and ranks with cotton growing, spinning, and weaving as an indigenous industry.

CHAPTER XXXI

EQUATORIA PROVINCE

By H. FERGUSON, B.SC. (Agric.), N.D.A., N.D.D., *Inspector of Agriculture*

'Here at the quiet limit of the world.' TENNYSON, *Tithonus*, i. 7.

GENERAL DESCRIPTION OF PROVINCE

Organization.[1]

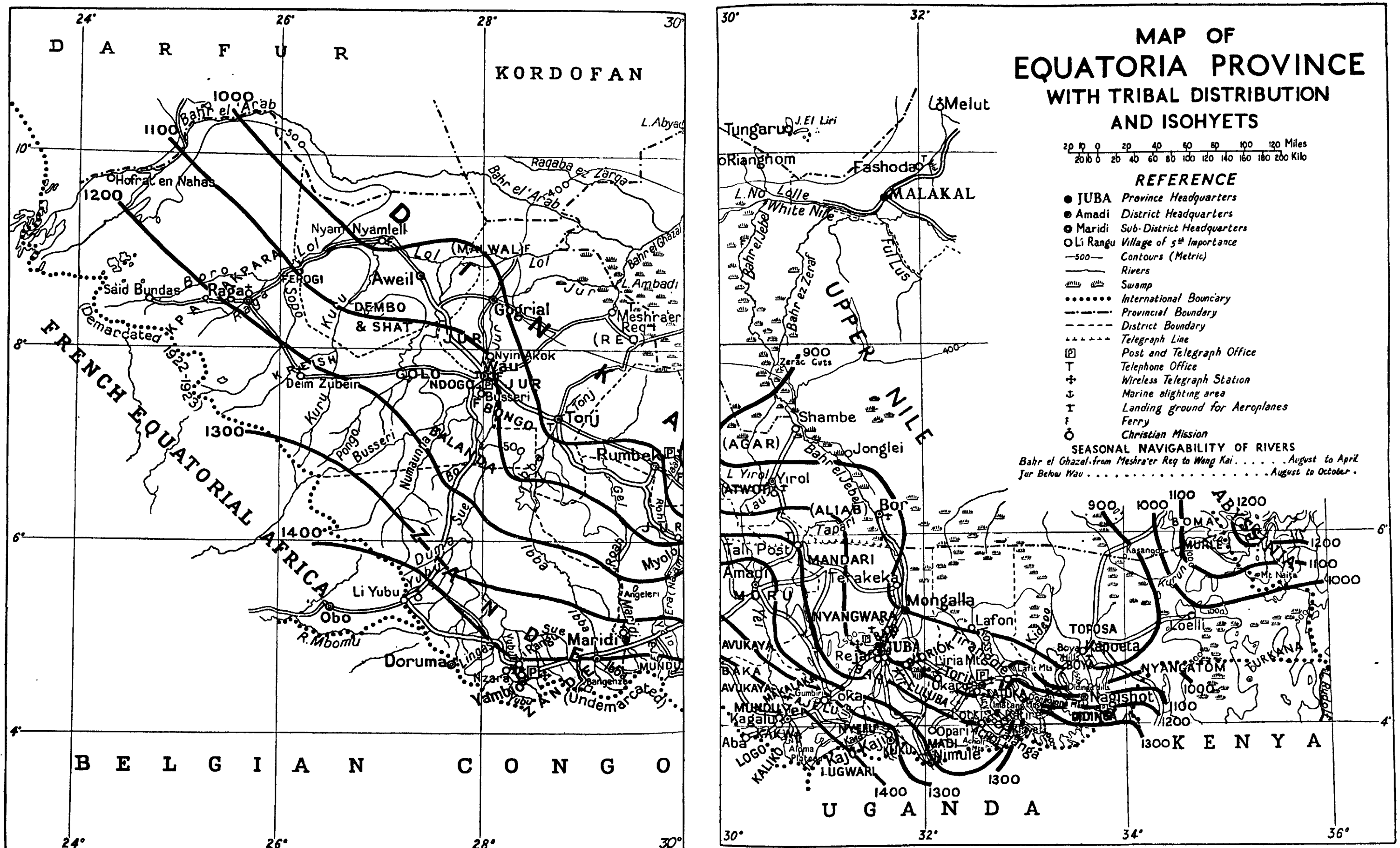
Equatoria Province is the most southerly province of the Sudan, lying roughly between latitudes 4° and 10° N. and between longitudes 24° and 36° E. of Greenwich. The area of the province is 159,025 square miles. In the north, Equatoria is bounded by the provinces of Kordofan, Darfur, and Upper Nile; in the east by Abyssinia; in the south by Kenya, Uganda, and the Belgian Congo; and in the west by French Equatorial Africa. The population of the province is estimated at 1,254,557 and appears to be on the increase.

Equatoria was constituted as a province in 1936 by the amalgamation of Mongalla and Bahr el Ghazal provinces. The administrative headquarters is at Juba, which is at the southern limit of the navigable reach of the White Nile. There are at present ten administrative districts, each being in charge of a District Commissioner with a staff of one or two Assistant District Commissioners. The following table gives the districts, their headquarters, areas, and populations. Reference to the map will show the relative positions of the areas and places mentioned.

District	*Area (sq. miles)*	*Population*	*District headquarters*
Juba	10,710	72,011	Juba
Torit	10,595	108,095	Torit
Eastern	18,335	46,037	Nagichot
Moru	13,970	54,982	Amadi
Yei	6,250	79,677	Yei
Zande	21,345	185,043	Yambio
Western	37,990	63,121	Wau (Raga Sub-District H.Q.)
Jur River	16,240	251,979	Tonj
Aweil	11,730	179,609	Aweil
Lakes	11,860	184,003	Rumbek (Yirrol Sub-District H.Q.)

District boundaries conform as far as possible with tribal boundaries, but often small tribal groups of completely different affinities are included in the same district. Formerly district headquarters were maintained at Opari, Tembura, Raga, Kajo Kaji, Maridi, and elsewhere, but following the policy of centralization and devolution, districts were amalgamated and their general administration centralized. This has been made possible by an extensive system of roads, the increased use of motor transport, and, above all, by the development of native administrations.

[1] For further details see 'Equatoria Province Handbook', vol. i, *Mongalla*. Sudan Government 1936.



MAP OF
EQUATORIA PROVINCE
WITH TRIBAL DISTRIBUTION
AND ISOHYETS
REFERENCE
JUBA Province Headquarters
Amadi District Headquarters
Maridi Sub-District Headquarters
Li Rangu Village of 5th Importance
—500— Contours (Metric)
Rivers
Swamp
International Boundary
Provincial Boundary
District Boundary
Telegraph Line
Post and Telegraph Office
Telephone Office
Wireless Telegraph Station
Marine alighting area
Landing ground for Aeroplanes
Ferry
Christian Mission
SEASONAL NAVIGABILITY OF RIVERS
Bahr el Ghazal, from Meshra'er Req to Wang Kai . . . . . . August to April
Jur Below Wau . . . . August to October
DARFUR
KORDOFAN
FRENCH EQUATORIAL AFRICA
BELGIAN CONGO
UPPER NILE
UGANDA
KENYA

In addition to the administration, the Medical and Agricultural Departments maintain services in most parts of the province, with Juba as their headquarters. The chief medical establishments are at Juba, Wau, Rumbek, Li Yubo (for sleeping-sickness), and Li Rangu (for leprosy). All parts of the province have hospitals or dispensaries and, where necessary, organizations are set up to combat particular diseases such as sleeping-sickness, leprosy, and cerebrospinal meningitis. The Agricultural Section of the Agriculture and Forests Department has its main stations at Juba, Kagulu (near Yei), Maridi, Torit, and Tonj, at

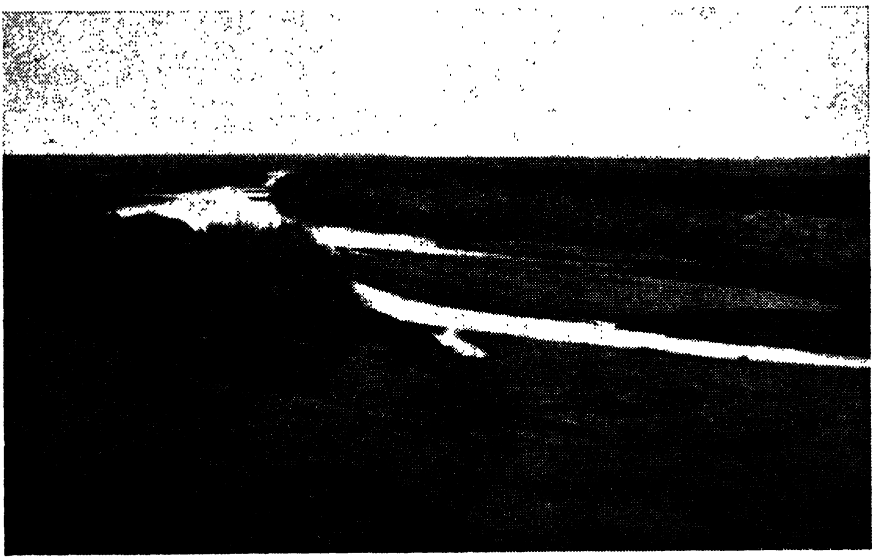


FIG. 363. River Lau and adjacent flood plains (*photo H. Ferguson*).

each of which a British Inspector is maintained. The Forests Section have saw-mills in the Wau, Yei, and Imatong areas. The Public Works Department have establishments at Juba and Wau from which all province works are administered. The Veterinary Department does not maintain a service at present, but with the development of the cattle industry no doubt it will.

Education in Equatoria Province is carried out through the medium of mission schools under the general direction, and with financial assistance, of the Education Department. There are two main missionary bodies working in the province—the Church Missionary Society (Protestant) and the Verona Fathers Mission (Roman Catholic). As far as education is concerned there is a co-ordinated policy of providing widespread literacy by means of a network of village schools, to which both bodies adhere. Teaching is carried out in village, elementary, central, and intermediate schools. The intermediate schools have a 6-years' course in English and produce junior officials required by the different departments in the province and higher-grade teachers. There are three of them: at Loka, Bussere, and Okaru. The elementary schools have a 4-years' course in

which the teaching is in the vernacular. The education of selected elementary schoolboys is continued for a further two years at central schools, largely for the purpose of providing teachers for improved village schools. In village schools the aim is to provide literacy in a 2-years' course. These schools are one of the main channels of the missions' evangelical work. There are trade schools at Wau, Loka, and Torit where carpentry, blacksmithing, &c., are taught.

The Sudan Defence Force maintains the Equatorial Corps in Equatoria Province with a peace-time strength (1939) of four companies. The headquarters of the corps was at Torit, and two companies were stationed on

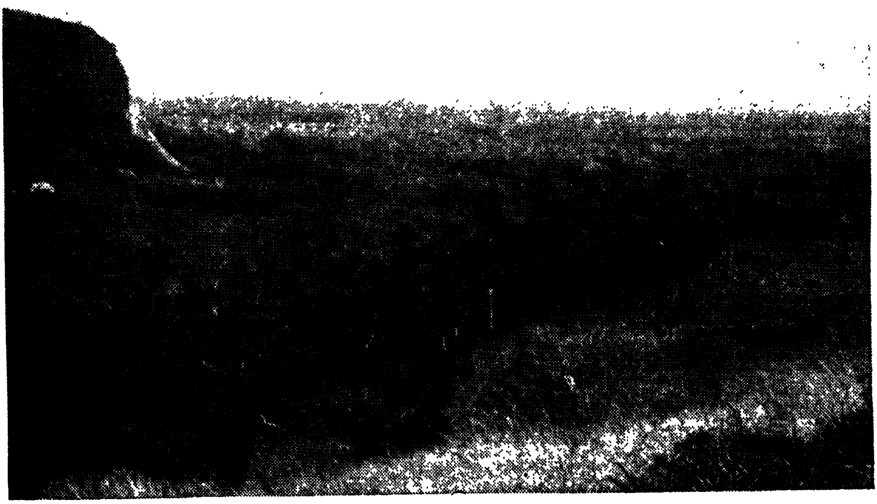


FIG. 364. Gallery forest and grass woodland on Aloma plateau (*photo H. Ferguson*).

the east bank and two on the west. The Equatorial Corps formerly played an important part in maintaining internal security, but now law and order have become firmly established and calls on the Equatorial Corps to maintain it are few.

Equatoria Province has three main outlets to neighbouring territories and provinces: the White Nile River route to the north, and the main roads to Uganda and the Congo to the south and west respectively. These three routes converge at Juba, which is therefore an important junction on the through overland routes between Egypt and East Africa and Egypt and the Congo Basin. The main ports served by the steamer services of the Sudan Railways are Juba, Terakekka, and Shambe on the Bahr el Gebel, and Meshra er Req and Wau (for 3 months only) on the Bahr el Ghazal.

The Juba service connects by motor transport with the Albert Nile steamer service of the Kenya and Uganda Railways, and with the Congo by the regular services of S.H.U.N. (Société du Haut-Uélé et du Nil). Besides the two trunk roads there is a good system of internal roads, most

of which are open at all seasons. These roads link the river ports with the interior and connect the main administrative centres. Reference to the map will show how these roads fit into the general economy of the province. As a rule animal transport is not used in Equatoria and all travel off the roads has to be done on foot. During the dry season, however, Arabs from Darfur with bull transport visit the western district for grazing and trading. All district headquarters except Yei, Amadi, and Aweil have either wireless, telegraphic, or telephonic services.

Trade, industry, and communications are interdependent in Equatoria. The long routes to the sea, coupled with expensive internal transport,

FIG. 365. Grass woodland in Luluba hills (*photo H. Ferguson*).

practically preclude export trade. There is little internal trade or trade with neighbouring territories and provinces, and consequently there is little impetus for the development of industries. Agriculture, animal husbandry, and the practice of other domestic arts and crafts are the chief occupations of the people. Amongst the more important crafts are house-building, blacksmithing, pottery, ochre making, making of native furniture, and a little spinning and weaving. The only tribes showing artistic tendencies are the Zande, Bongo, and related tribes. There is a slight export of agricultural and forest products, the main ones being timber, hides, cotton, chillies, honey, bees-wax, sesame, and coffee. Timber production is carried out by the government Forest Section, and cotton production is sponsored and controlled by the Agricultural Section of the Agriculture and Forests Department. Other commodities pass through ordinary trade channels, i.e. through the shops of Greek and Arab traders who are established in all centres.

The mineral resources of the province are iron—low-grade laterite ore being found everywhere—copper at Hofrat el Nahas, limestone, gold, asbestos, and mica. These resources were investigated by the Nile Congo

Divide Syndicate which decided against large-scale exploitation. Gold and asbestos are the only ones worked at present, a concession having been granted to a small private firm. Iron smelting used to be practised by many tribes.

History of Equatoria Province[1]

At the formation of Equatoria in 1936 the old provinces of Mongalla and Bahr el Ghazal remained unchanged except for the suppression of their common boundary and the establishment of a single administration.

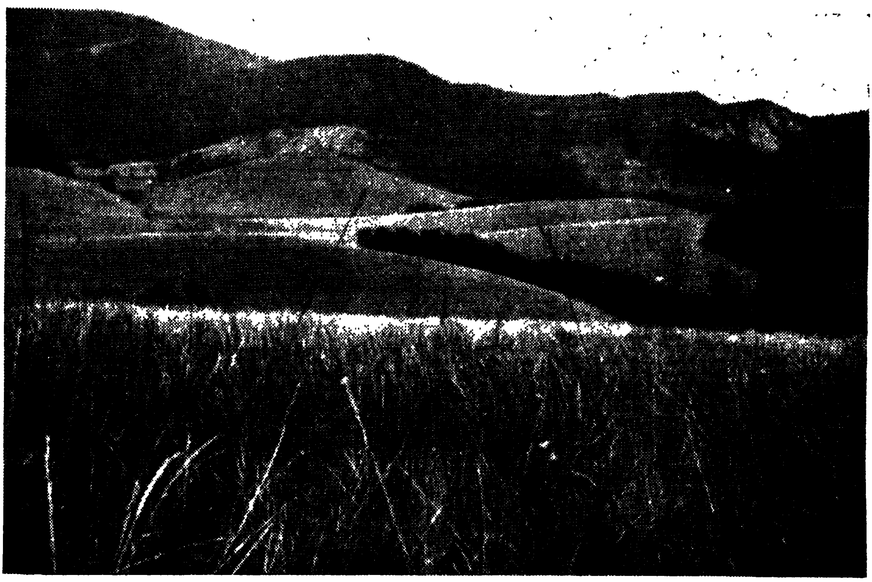


FIG. 366. Mountain meadow and cloud forest at 9,000 feet in Imatong mountains (*photo H. Ferguson*).

The foundations of Equatoria Province were laid much earlier than 1936. The Sudd (see map at p. 876) was an effective barrier against entry from the north till about the middle of the nineteenth century, when explorers and early missionaries pushed their way through it to the south. Amongst them were such famous discoverers of Central Africa as Baker, Schweinfurth,[2] and Junker.[3] Bahr el Ghazal was opened up earlier than Mongalla, and under Egyptian and Dervish rule was of chief importance as a source of slaves for the northern Sudan and Darfur. Mongalla being less accessible was not ravished to the same extent. The reductions in human and cattle populations during the Dervish period were so immense that the losses sustained by many tribes will never be made good. With the decline of Dervish power at the end of the century both the French and the Belgians advanced from the west in an attempt to reach the Nile. The Belgian

[1] Hill, *Bibliography of the Anglo Egyptian Sudan.* This contains references to publications of early administrators and explorers.

[2] Schweinfurth, *The Heart of Africa.*

[3] Junker, *Travels in Africa.* Both these are full of interest.

attempt culminated in their leasing of the Lado Enclave,[1] and the French ended in the Fashoda episode. The Lado Enclave was returned to the Sudan by agreement in 1910 and, with some simultaneous and subsequent adjustments in the Uganda and Kenya frontiers, the frontiers were then fixed in their present positions. Since the beginning of the Anglo-Egyptian administration the course of events has been normal—the establishment of law and order, the improvement of communications and trade and of medical, educational, and other services.

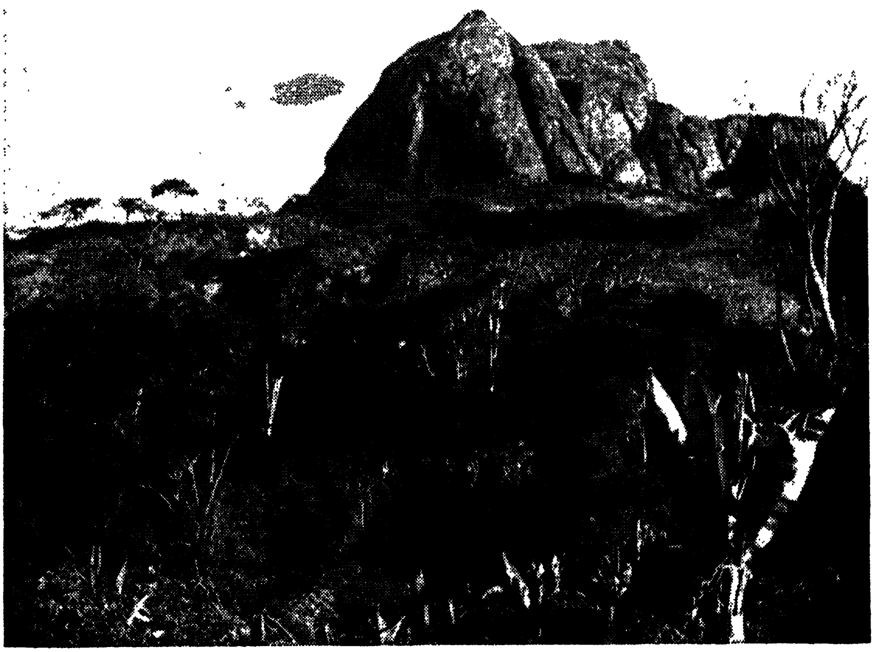


FIG. 367. Imatong Hills. Wild bananas and forest below Jebel Garia (8,281 ft.) (*photo H. Ferguson*).

Physical Features of Equatoria

There is a general fall in elevation from the south to the north and from the perimeter of the province to the Bahr el Gebel and the Bahr el Ghazal. The entire frontier of the province west of the frontiers of Uganda and the Belgian Congo runs along the watershed of the Congo and the Nile. The Nile-Congo divide consists of gently hilly country between 2,200 and 3,500 ft. above sea-level. This falls away gently and merges into the ironstone plateau—a flattish area of country about 2,000 ft. in elevation, which occurs between the divide and the low-lying country along the rivers. It will be seen from the map that the Nile-Congo divide is drained by a series of rivers running in a northerly direction into the Bahr el Ghazal, which carries their water eastwards to meet the Bahr el Gebel at Lake No. The depression of the Bahr el Ghazal consists of extensive flood plains ('toich' in Dinka) merging into papyrus swamps.

[1] Stigend, *The Lado Enclave.*

The 'toich' reach their greatest development along the tributaries after they leave the ironstone plateau, and the swamps along the course of the Bahr el Ghazal itself. The Bahr el Gebel river receives most of its water from Lake Victoria. Between Nimule and Rejaf the river flows through a well-defined gorge with occasional rapids which make navigation impossible. North of Rejaf the river spreads out into swamps and flood plains, the latter being considerably smaller in extent, and less liable to flood than those of the Bahr el Ghazal. To the east of the Bahr el Gebel

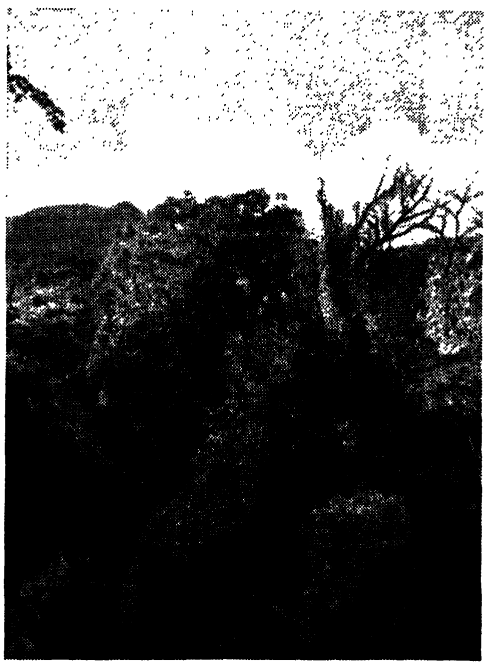


FIG. 368. Mount Kinyeti (10,456 ft.), the highest peak in the Imatong Hills. Note luxuriant cloud forest in foreground (*photo J. F. E. Bloss*).

there is a series of large, well-defined mountain masses. The Imatong range, which is the largest, contains Mt. Kinyeti (10,456 ft.), the highest mountain in the Sudan (Fig. 368). The drainage from these mountains is carried north and gets lost in the plains lying between Equatoria and Upper Nile Provinces. These plains are swamps during the rains and waterless wastes during the dry season.

The main features of the geology of the province have been dealt with in Chapter VI. The large and small mountain masses and the higher hills of the Nile-Congo divide are all composed of the basement complex of schists and gneisses with intrusions. Except where it is overlaid by ironstone or more recent deposits, this is the parent rock of the Equatoria soils. The ironstone blanket covers a wide area, being found in a number of places on the east and west banks as well as on the ironstone plateau itself. There are alluvial deposits along the river banks, and grey cracking clay

occurs extensively on the east bank north and east of Torit and Kapoeta. What appears to be a pale sub-ironstone clay is exposed at a few places.

Climate, Soil, and Vegetation

The rainfall in Equatoria varies from only a few inches per annum in the south-east to nearly 60 inches on the Nile-Congo divide. As will be seen from the map on p. 876, the rainfall lessens from west to east and from south to north. More important than the decrease in rainfall is the poorer distribution which accompanies it. In the south-west part of the province the rainfall is evenly distributed between the months of March and November with occasional showers during the dry season (December to February), while in the east and north the season is not only shorter but showers occur less frequently and less regularly, and are often of greater volume.

FIG. 369. Gallery forest on river Yei (*photo H. Ferguson*).

The climate of the southern Sudan is influenced locally by the topography. Hilly regions generally get more rainfall than the plains, and on the Imatong, Acholi, and other east bank mountains the western and southern slopes get a plentiful rainfall, while the northern and eastern ones get a low rainfall. In the east of the province a very dry pocket is formed between Kapoeta and Lake Rudolph.

Temperatures in the province vary with the altitude and the rainfall, though in the south-west, with its long wet season and rich vegetation, the climate is much cooler than would be expected. The effect of rainfall (and soil moisture) on soil formation and vegetation has been stressed in Chapters IV and VIII. In Equatoria there occur the groups of soils described by Dr. Greene as the ironstone, the 'toich', the red loam, and the alkaline catenas. It will be seen later that the distribution of these soils corresponds closely with the rainfall-topography basis of Dr. Greene's classification. From the agricultural point of view corresponding members of different catenas are often very similar.

The vegetation of Equatoria Province ranges from almost desert to almost tropical rain forest. The characteristic, and by far the most common, type in the province is broad-leaved woodland. Unless modified by local factors this type occurs everywhere in the province except in the drier areas east of Kapoeta and north of Aweil where acacia desert scrub and acacia grass woodland respectively are found. On the flood plains there is a very rich grass association almost devoid of trees, and in the permanent

FIG. 370. Grass woodland in Zande Area
(*photo H. Ferguson*).

FIG. 371. Cleared grass woodland at Yambio
(*photo H. Ferguson*).

swamps there is a characteristic papyrus association. In the valleys and depressions in the wetter areas, gallery forests and depression forests occur. The former are found along the Nile-Congo divide and in the foot-hills of the eastern mountains, and the latter at Azza near Maridi, and at Laboni, Lotti, and Talanga in the foot-hills of the Imatongs.

Altitude zonation is seen in the Imatongs and neighbouring ranges, where cloud forest, mountain meadow, and the transition types below each of these are found. All types of vegetation have been adversely affected by fires, grazing, and cultivation. The general effects of these

FIG. 372. Elephant grass on Aloma plateau (*photo J. G. Myers*).

have been discussed elsewhere[1] but admitting the existence in places of a balanced fire-climax vegetation, it bears repeating that uncontrolled fire does immense and irrevocable damage to vegetation and soil.

Tribal Divisions[2, 3]

The number and variety of tribes in Equatoria Province are large, and it is impossible to describe them in detail, or even to group them satisfactorily. All are negroid, though of great diversity in their affinities, and consequently in their physical appearance, customs, and languages. Except for recent mission converts, and for one small tribe (the Ferogi) which is predominantly Muslim, all are pagans with a variety of religious beliefs in which superstition and magic play a great part. All are still very primitive, though it already appears that many tribes have the intelligence and initiative to adopt civilized ways. Ethnologically the main groups of negroids represented in the province are Nilotics and Nilo-Hamitics,

[1] *The Report of the Soil Conservation Committee.* Sudan Govt. 1944.
[2] Seligman, *Pagan Tribes of the Nilotic Sudan.*
[3] Nalder, *A Tribal Survey of Mongalla Province.*

both long-skulled; Bari-speaking (not including Bari) and Moru-Madi groups, medium- to round-headed, dark-skinned peoples; and Bantu and West African Negro types, round-skulled, lighter-skinned peoples, originating mainly from the west. The last two groups contain a very miscellaneous collection of tribes.

The chief Nilotic tribe, and by far the largest tribe in the province, is the Dinka with an approximate population of 500,000. The Dinka are tall,

FIG. 373. Bamboos make useful building poles in Equatoria Province. Forests of bamboo are not, however, very plentiful (*photo J. F. E. Bloss*).

slim, and dark-skinned. They form a solid block inhabiting the flood plains of the Bahr el Ghazal area. Their main and almost sole interest is cattle, with which most of their customs and habits are connected. The Dinka are divided into a number of distinct groups. The other Nilotic tribes in the province are sections of the Jur and Balanda tribes in Jur River and Western districts and the Acholi on the Uganda border. These tribes have the general characteristics of the Nilotics and speak Shilluk dialects, but are agriculturists rather than pastoralists. The Nilo-Hamitic group is in many ways similar to the Nilotic. Where pastoral conditions are favourable they are keen cattle-owners and show little interest in agriculture. Most of the tribes inhabiting the east bank of the Bahr el Jebel

belong to this group; the Bari, Latuka, and Toposa being the largest. Related to the Nilo-Hamitics on the east bank there are a few hill tribes (Didinga and Longarim) the people of which are both cattle-owners and good agriculturists. The Nilotics and Nilo-Hamitics have a reputation for intelligence coupled with conservatism.

The Moru-Madi group consists of the Moru, Avukaya, Madi, and Kaliko tribes inhabiting the Amadi district and parts of the Uganda border. The Bari-speaking group inhabits the eastern part of Yei district and parts of Central district. The main tribes are Kakwa, Fajulu, Kuku, and Nyangwara. Both Moru-Madi and Bari-speakers are by inclination cattle-owners, but, having lost most of their cattle by Dervish raids or disease, they are now mainly agriculturists. The Moru and Kaliko are the best agriculturists of both groups.

There is little similarity between many of the tribes in the last group. The main tribe and the second largest in the province is the Zande, with an approximate population of 200,000. In appearance, customs, and interests they are diametrically opposite to the Dinka. They are short and squat, are very good agriculturists, and have never owned cattle. They occupy the south-western corner of the province (Zande district). The Zande entered the Sudan from the south-west and were rapidly advancing till Egyptian and British rule stopped them. The other tribes grouped with the Zande are in common with them good agriculturists and have never owned cattle. The tribes included are Baka and Mundu in Maridi and western Yei districts; Ndogo, Golo, Banda, Kreish, Bongo, and other small tribes in Western district. All these tribes are small in numbers.

Generally speaking, the best pastoral areas and the best agricultural areas are the most thickly populated, and it is the strongest tribes—the Dinka and the Zande—which occupy the country best suiting their requirements. There are large areas which are without population because of poor soil, lack of surface water, or their remoteness. The largest unpopulated areas are the ironstone plateau, because of thin soil and lack of surface water; the clay plain north of Torit, because of lack of water; and the northern part of the Nile-Congo watershed because of its remoteness. The last mentioned is good agricultural country, is well watered, and before the slaving era must have supported a fair population. On the dry cracking clay plains east of Kapoeta the population is nomadic, and consequently sparse. The tribal distribution is shown on the map.

It will be seen that the natural conditions and native culture in Equatoria Province are widely different from those of the northern Sudan and are in fact much more closely associated with those of Uganda and other central African countries.

EQUATORIA AGRICULTURE[1]

Chief Agricultural and Grazing Areas

The best agricultural areas occur in the regions of higher and better distributed rainfall, and the best grazing areas in the regions of lower and less

[1] Practically nothing has been published about Equatoria Agriculture, but there is a good deal of detailed information available in unpublished departmental reports.

regular rainfall. The areas mentioned above as being practically unpopulated are, of course, of no importance, though the northern part of the Nile-Congo divide is good agricultural country and pockets of good land occur, and are cultivated, on the ironstone plateau. The occurrence of the tsetse fly (*Glossina morsitans* Westw., the vector of trypanosomiasis) is the main factor limiting the distribution of cattle in the province. Though a detailed survey of its distribution has not yet been made, it appears to be of most

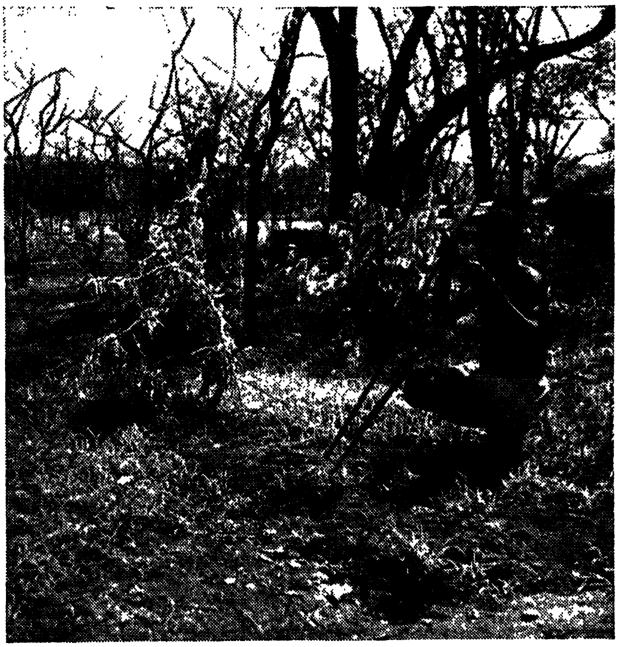


FIG. 374. Much of southern Equatoria Province is without farm animals due to the presence of *Glossina morsitans* Westw. The native shown has come upon tracks of Giant Eland. *Glossina morsitans* is plentiful (*photo J. F. E. Bloss*).

frequent occurrence on the ironstone plateau and to be found less frequently on the Nile-Congo watershed, the fringes of the ironstone plateau, and certain areas on the east bank. It does not occur in the areas of open vegetation. Cattle are therefore precluded entirely from the ironstone areas and occur only in pockets of open vegetation in the other areas within the tsetse limits. Outbreaks of rinderpest and bovine pleuro-pneumonia are of fairly frequent occurrence and reduce the cattle population from time to time. Where the reduction is severe, as it has been in Yei and Moru districts, the vegetation may revert to a type of bush thick enough to give protection to *Glossina morsitans* Westw. The growth of crops is affected by the normal factors of climate and soil, and in no case do pests or diseases have the limiting effect on any crop that tsetse has on cattle.

The following is an empirical classification of the most important agricultural and grazing areas:

(1) The Zande area (including other similar areas).
(2) The Yei area (including other similar areas).
(3) The predominantly sandy and sandy loam areas.
 (*a*) on the fringes of the ironstone plateau;
 (*b*) on the east bank of the White Nile and Central district;
 (*c*) in the Western district (including northern Zande district).
(4) Areas of apron cultivation.
(5) Riverain areas:
 (*a*) the flood plains of Bahr el Ghazal;
 (*b*) the valley of the Bahr el Gebel.
(6) The dry eastern area.
(7) The Kajo Kaji area.

In the above classification the conditions characteristic of each group are not easy to define, as they vary within the group, merge into those of neighbouring groups, and occur in areas outside the typical areas. Its main purpose is to serve as a basis for more detailed consideration of the agriculture of the province. It will be found that there is a close relationship between these agricultural groups and climatic, topographic, and soil conditions, which carries a stage further the relationships between climate, soil, and vegetation already noted. It will later be noted that native agricultural practices are adapted to the same combination of conditions. These areas can best be visualized on the map by referring to the tribes who inhabit them.

Agricultural Features common to Most Areas

Before describing the above agricultural areas in detail the main points common to the agriculture of most of the areas will be mentioned.

All crops in Equatoria are rain-grown. Except where land is scarce, shifting cultivation (see Chapter XV) is the rule. In all non-cattle areas this is practically the only method of bringing back soil fertility, and at the present stage of agricultural development it is the most practicable way of doing so. In most places there is ample space for shifting cultivation, and though there are tribal laws of land tenure they allow of practically free movement. Tribal practice regarding land tenure and allocation generally requires a chief, rain-maker, or other functionary to approve and allocate new land, which may at the same time receive some sort of blessing to make it fertile. Separate cultivations are made by each household, a man allocating an area to each of his wives, but these are often grouped with those of other relations. As only hand-hoes are used, there are no large individual cultivations. Rain-making and magic play an important part in agriculture, the former amongst Nilo-Hamitic, Bari-speaking, and Nilotic tribes, the latter amongst Zande and related tribes. A rain-maker's functions are to bring rain when required and advise on sowing dates and crops generally. Magic is practised by all tribes, and its main functions in agriculture are to provide antidotes against evil influences or to encourage good influences upon the crops. Certain plants, particularly *Euphorbia* and *Synadenium* sp., are often planted for this purpose, especially when new cultivations are being opened.

FIG. 375. Open forest near Yambio, River Sui. Full of game (and also *Glossina morsitans* Westw.) in the dry season (*photo J. F. E. Bloss*).

FIG. 376. The River Sui. The only river rising on the Nile–Congo divide to reach the

FIG. 377. A fierce forest fire near Sources Yubo (*photo J. F. E. Bloss*).

In order to keep the population away from tsetse- (*Glossina palpalis* R.D.) infested streams, and to facilitate sleeping-sickness and administrative inspections, the entire population in sleeping-sickness areas (Yei and Zande districts) was moved on to the roads. As the roads are frequently built on watersheds these people have had to use in places the thin erodable soils on the ridges, and their crops have in consequence suffered. These regulations are now being relaxed.

FIG. 378. Grass fire in the Kinyeti valley with cloud forming above. As seen from Itobol (over 6,000 ft.) in the Imatong Hills (*photo O. W. Snow*).

Erosion is to be seen in most areas, but is as yet not a serious problem in many of them, though it is a problem which should not be neglected. There is not much gully erosion, but sheet erosion is common and on the ironstone plateau there are areas of bare ironstone from which the surface soil has been completely eroded. One of the main factors contributing to general erosion is the grass fires made annually by the natives for hunting and collecting honey. Grazing in certain places is an important contributory factor. In many places cultivations have features which prevent rather than encourage erosion.

A large variety of crops are grown by the purely agricultural tribes. The pastoral tribes have a poor selection, though they usually possess some good quality sorghums. This means that the tribes to the south-

west are well furnished with all kinds of crops and those to the north and east have few kinds except sorghum. It seems certain that all except the older crops (e.g. sorghums) have entered the country from the south-west via the Zande and related tribes. At the present time root crops (cassava and sweet potatoes) are spreading northwards and eastwards from the south-west, while at the same time the Zande are voluntarily introducing new and better varieties from the French and Belgian Congos. Cassava and sweet potatoes are resistant to both drought and locust attack and are therefore being vigorously encouraged as a guarantee against famine in areas where they are not grown. Practically all tribes know sorghum, maize, sesame, cow peas, ground-nuts, and pumpkins, and grow them if conditions are suitable. Other cereal crops are fairly widely known and are grown whenever local conditions are suitable. Besides the root crops, certain types of fruit-trees and native vegetables are confined to the south and west. All tribes grow okra ('bamia') and Jew's mallow ('mulukia') as vegetables; gourds (*Lagenaria vulgaris* Seringe) for making dishes and for the edible seed produced by one variety; Deccan hemp (*Hibiscus cannabinus* Linn.) for rope-making fibre, and tobacco and hashish (secretly) for smoking. All tribes use wild plants for food, fibre, and medicine.

In nearly all areas mixed cropping is practised: sesame and eleusine; sesame, eleusine, and sorghums; maize and cow peas; and maize and pumpkins, being the commoner combinations. In the absence of mechanical cultivation this method of sowing is thoroughly satisfactory. Except in the case of maize, ground-nuts, and sometimes cow peas and sorghums, seed is usually broadcast. Sowing is done after the rains except in some dry areas where it may be done before the rains. Cultivation is done entirely by hand, using the tools described in Chapter XV. Harvesting is done in the case of cereals and sesame by cutting off the heads, and of cow peas and other legumes by picking the pods; threshing is done with sticks or by pounding in a native mortar; grinding is done in a mortar or between two stones: storage is done in specially built store-houses as described in Chapter XV. Underground storage is not practised. Seed selection is not usually practised.

Crops in Equatoria Province are affected by a large number of pests and diseases which cause considerable damage to, though never complete loss of, crops. Descriptions and distribution of the most important of these are to be found in Chapter XVI. Though many pests and diseases are potentially dangerous, especially if areas of cultivation were to be increased, cassava mosaic is the only disease which has reached epidemic proportions throughout the province. There are many others which cannot be neglected. Locusts are not a major problem in Equatoria as there is usually enough food for them on the indigenous vegetation.

With regard to livestock, though cattle cannot be kept in all areas all tribes have a few goats, a few poultry, and usually a few sheep. These are often maintained as a form of wealth, being often used for bride-price. The tribes who own cattle also look on them primarily as a form of wealth and use them as bride-price. Animals are of course used also as a source of milk and meat, but where they are scarce, as in the south-west, there is not nearly enough meat available to satisfy the dietary requirements of

the natives. In all areas animals are herded by small boys or young men during the day and collected into some kind of corral at night. Animals are never stall-fed, nor are special forage crops grown for them. Their dung is used to a greater or less extent as manure. They are not used for drawing any implement or for threshing.

Zande Area

This area comprises all the land along the Nile-Congo watershed between Tembura and Maridi and is situated mostly to the south and west

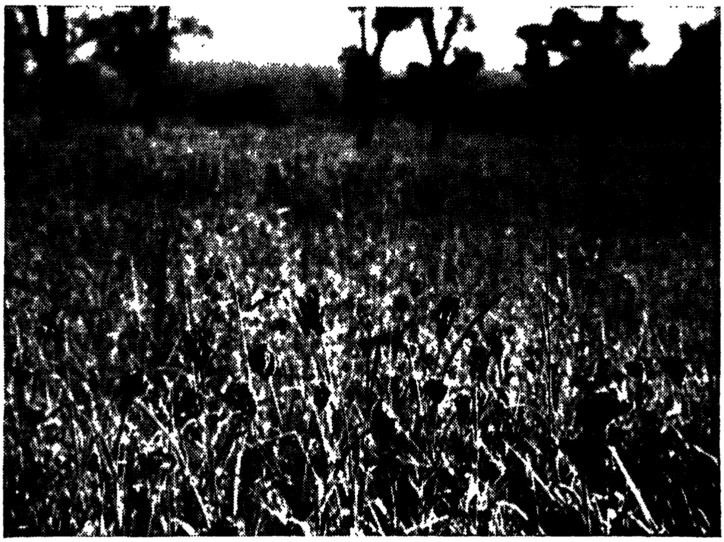


FIG. 379. *Eleusine coracana* Gaertn. is one of the main grain crops of Central Africa. The Azande mix it with cassava to make a porridge meal and use it extensively to make a good brew of beer (*photo J. F. E. Bloss*).

of the Tembura–Yambio–Maridi road. The rainfall in this area is about 1,500 mm., and falls mainly from March to November with a little in the dry season. Most of the streams are permanent. The soil falls into groups 1 and 2 (mainly group 1) of the ironstone catena, with a little of the red loam type in Maridi district. Where the country is not too fire damaged these soils contain much organic matter and probably have reserves of nitrogen like the tall grass areas in Uganda. The richer soils are to be found in areas south and west of Yambio and south and south-west of Maridi, both of which support a dense population. The primary vegetation consists of dense woodland, with gallery forest in all the river valleys, and occasional forest trees in the broad-leaved woodland. There is much bush and little grass. Gallery forest is characteristic of the area, though it varies in width and is replaced in places by swamps. In the better areas mentioned above the wetness and the nature of the vegetation itself protect it from severe fires and so protect the soil from erosion and loss of organic matter which would no doubt take place were fires severe. In these areas regeneration of vegetation after cultivation is very rapid and

complete, and thus, except from the nutritional point of view, the lack of livestock is of no importance. In addition to these richer areas Zande land contains considerable areas of thinner soils and secondary vegetation which are severely burned annually and show distinct signs of sheet erosion. Elephant grass grows in this area and could be used as a regenerative crop, as it is in the somewhat similar areas of Uganda. The soil and climate are suitable for a very large variety of field and plantation crops. It is all tsetse country.

The inhabitants of the area are mostly Zande with Baka Mundu and Avukaya in Maridi sub-district. They are all keen and good agriculturists and have never been known to own cattle. The population used to live entirely on the roads, but a recent relaxation of the regulations has resulted in much of the population so affected returning to sites of their own choosing. A great variety of crops are grown for food, domestic equipment, medicine, and magic. Two crops per year of eleusine, cow peas, maize, and sesame are usually taken. Eleusine (Fig. 379) is the main grain crop, and all other common cereals and root crops are grown. Sesame, ground-nuts, and cow peas are also grown as field crops. Upland rice, lima beans, yams, coco yams (*Xanthosoma sagittifolium* (L). Schott), green gram beans, and all the vegetable and other useful crops are grown on a small scale generally. Chillies are grown everywhere. Mangoes, bananas, pine-apples, pawpaws, and guavas are found everywhere; coffee, oil palm, citrus fruits, and sugar-cane (for chewing) are found where they have been encouraged by the Government. This area is therefore secure against famine, though lack of cattle and scarcity of other livestock mean that the diet is extremely deficient in animal protein.

FIG. 380. Maize stacked on frames for drying. Yambio district (*photo J. F. E. Bloss*).

The varieties of crops grown are generally good. There are several varieties of eleusine which, though distinct in appearance, differ little in other characteristics and are generally grown together. There are two main sorghums: a red one (Mombagu), and a white one (Vunde or Ndola) grown mainly in the Maridi area which is considered one of the best duras in the province. Bitter and sweet cassava are grown in about equal quantity. The common variety of bitter cassava (Bazomangi) is rather susceptible to mosaic disease, while the sweet varieties, and a bitter

FIG. 381. Maize in storage is subject to attack by insects. The Zande store is like this (*photo by J. F. E. Bloss taken at Li Rangu, the largest leper colony in the Sudan*).

variety (Karangba) recently introduced from French Equatorial Africa, are resistant. There are four or five varieties of ground-nuts, the one most generally grown being a good yielding bunch type with 4-seeded pods. It is very similar to Kordofan Central African which, however, has yielded better in trials and is now being bulked for distribution. A large-seeded, large-podded, weevil-resistant variety, and a climbing variety (Abangba) of cowpea are noticeably good types which are commonly grown. The upland rice is of good quality, gives good yields, and is generally a satisfactory crop. Its cultivation is not extensive but is on the increase.

This area is one of great agricultural potentialities, but for export purposes is too remote for any except high-value crops. Chillies, bees-wax, and honey are universally collected and exported through ordinary trade channels. Coffee and cotton have been introduced by the Government as possible money crops.

Coffee planting (*robusta* types only) by the natives is encouraged, though since the fall in price of Sudan coffee in 1936 large-scale expansion has not been encouraged. Coffee is marketed through ordinary trade channels.

American cotton has been grown in Maridi area since 1928, when a ginnery was established at Maridi. It is now accepted by the natives as part of their normal cropping system and is fairly soundly established.

FIG. 382. Baskets made of grass fibres by the Zande for storing food and collecting white ants when in the forest (*photo J. F. E. Bloss*).

In early days compulsion was used, and 1935/6 gave the maximum production so far obtained of 32,757 small kantars. Since compulsion has been withdrawn and the price reduced, production has fallen (7,177 small kantars in 1940), but the basis of the industry is now much sounder and future expansion possible. A system of group farming now being tried holds promise as a good method for increasing the cotton production and improving agriculture generally. In this, groups of farms, laid out to prevent erosion, receive special supervision and are run on fixed rotations, individual cultivations including 2 acres of cotton and all the household's food crops. Extensive trials conducted throughout the rest of the Zande area from Tembura southwards have proved conclusively that cotton is a crop suitable for most parts of this area. The area of cotton production and yields in the Maridi area and in the experimental plots up to 1939/40 season are given in the following table:

Seed Cotton Production in Maridi Ginnery Area

Area	Total production 1928–40 (small kantars)	Number of feddans		Yield (small kantars)		Yield per feddan (small kantars)		Price per kantar seed cotton	
		Average 1936–40	1939–40	Average 1936–40	1939–40	Average 1936–40	1939–40	Average 1936–40	1939–40
Maridi . .	140,028	3,600	2,080	11,669	6,797	3·25	3·7	26 P.T.	28 P.T.
Experimental plots in all Zande area	..	125	125	506	487	4·05	3·87	..	..

The variety of cotton grown in recent years has been 511 D, but trials covering imported and locally bred types are conducted annually to find more suitable varieties. Apart from general improvement in yield and quality, blackarm resistance, higher ginning out turn, earliness, jassid resistance, and longer staple[1] are the qualities being aimed at. The last is considered of importance as the heavy transport costs make it essential to have as high a priced cotton as possible. Helopeltis, pink bollworm, lygus, and jassid are the main pests and blackarm the most severe disease. Ramularia is frequent but does little damage.

At Maridi an experimental farm and entomological laboratory are maintained. At the experimental farm, cotton variety, spacing, and date of sowing trials, food-crop variety trials, and rotation and other cultural trials have been and are being conducted, and have provided data useful in native agriculture. New food crops and improved varieties have been introduced. At present mosaic-resistant cassava varieties are being investigated. The farm also acts as a centre for distribution of coffee, oil palm, and fruit-tree seedlings. The entomological laboratory has been occupied mainly in collecting information concerning bollworm and Helopeltis. Besides the farm at Maridi the excellent 'merkaz' farm at Yambio and the Medical Department farms at Li Rangu and Li Yubo have done much to assist native agriculture. At all four stations dairy herds are maintained in clearings, for supplying the residents with milk and butter. Much information on pasturage and cattle husbandry in these areas is being obtained.

There are three small isolated areas similar in soil and climate to the Zande area—the Aloma plateau south of Yei, inhabited by Kaliko; the southern and western foot-hills of the Acholi Hills, inhabited by Acholi; and the western foothills of the Imatongs, inhabited by Latuka. The soils of these areas fall into group 2 of the red loam catena, and because of their high organic matter content and good mechanical condition are similar agriculturally to those of Zande area. The vegetation is similar but more open than in Zande area. On the two east bank areas a much smaller variety of crops is grown and fruit-trees are practically absent. Coffee is grown to a limited extent in all these areas, and is also grown on and near the

[1] With the establishment of a spinning-mill in Zande land longer staple would no longer be required; indeed shorter staple might become desirable.—*Editor.*

Aloma plateau on the only privately managed estates in the province, named Iwatoka and Kabengere respectively. Potatoes have been grown with limited success on the Aloma plateau and in the Acholi Hills. A little irrigation is practised in parts of the Kinyeti valley.

The Yei Area

The Yei area includes all the populated part of Yei district except Kajo Kaji and the Aloma plateau. The rainfall is about the same as in the last area, the average for Yei being 1,438 mm., but the distribution is not so good

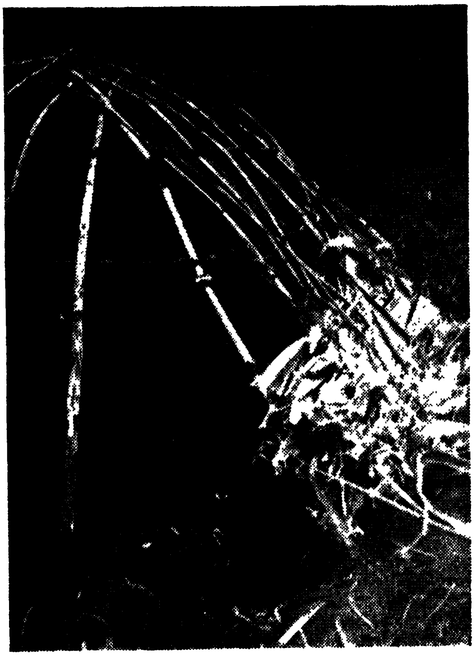


FIG. 383. White ants are a universal source of food in Equatoria Province, but what they add to the diet in nutritional terms is not yet known. This ant hill near Issore in the Imatong mountains is being covered in anticipation of a nuptial flight. The hole in front has been made for collecting the flying termites as they emerge (*photo J. F. E. Bloss*).

and intervals between showers tend to be longer. The vegetation is of a drier type, being grass woodland with no undergrowth, much grass, and sparser gallery forest. The soils of the area mostly fall into groups 2 and 3 of the red loam catena with some ironstone soils containing pea iron. They are stiffer, have much less humus, are more compact, less absorptive, and less retentive of water, than those of the Zande area. The large amount of grass results in intense fires which prevent humus formation and expose the soil to erosion. The nature of the soil itself prevents serious gully erosion, but there is a good deal of run-off, and the soil becomes very firmly compacted and deteriorates rapidly in mechanical

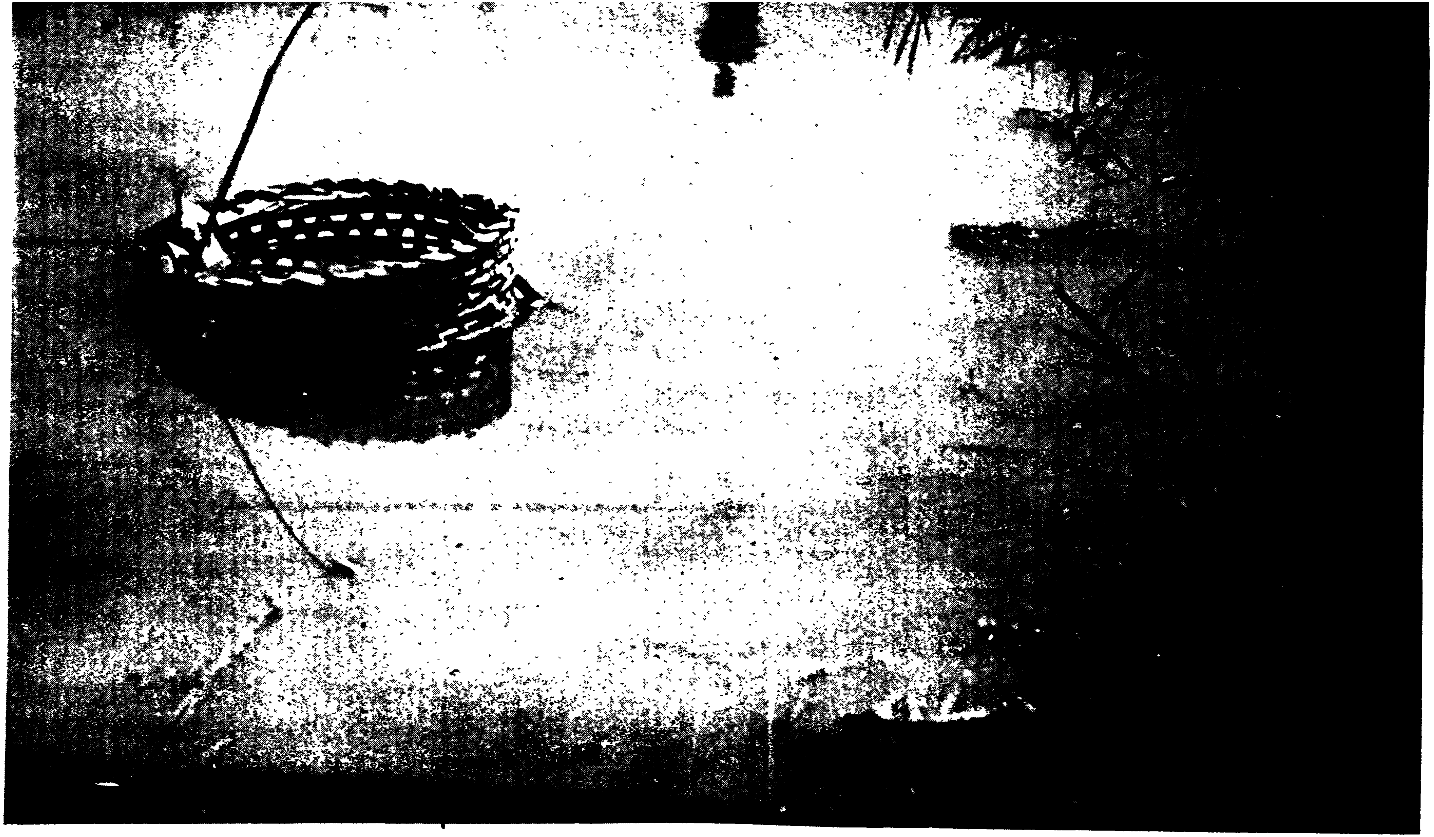


Fig. 384. Beer-making. Grain being germinated in water prior to being ground up. A Zande method (*photo J. F. E. Bloss*).

FIG. 385. *Calopogonium* is a useful cover crop in spear grass country (*photo J. F. E. Bloss*).

FIG. 386. Oil palms and mangoes at Kagulu (*photo H. Ferguson*).

condition when exposed. Fertility is maintained by shifting cultivation, but after the area is abandoned for recuperation the vegetation does not return to the original bush but may become pure grass, spear grass (*Imperata cylindrica* Beauv.) being very common after cultivation. This grass land appears to revive the soil satisfactorily, though it probably may continue to be low in organic matter. In reopening this grass land the practice of sowing cow peas without burning or clearing off the hoed grass is followed. This appears to be a very sound method of making the fullest use of all sources of nitrogen for the subsequent crops. In favoured

FIG. 387. Native women preparing cassava flour near Yei (*photo H. Ferguson*).

situations the soils are much better, and if fire were prevented over a long period a great improvement in soil and vegetation would be certain. Tsetse are not very common in this area and many pockets of open country exist.

The inhabitants of the area are Bari-speaking tribes (Kakwa, Fajulu, and Nyefu) in the eastern end and Mundu, Makaraka, Baka, and Avukaya in the western end. The Bari-speakers were cattle-owners, but most of their cattle have been lost through disease. A few goats, sheep, and poultry are kept, but the diet is now largely meatless. The population all live along the roads, but with relaxation of restrictions are gradually moving off. In Yei district the poor and exhausted condition of the roadside belt is particularly noticeable. Two crops a year may be taken, but the main sowings are in July and August, the second half of the rains being thus the main cropping season. This late cropping is characteristic of Yei district, is not practised in any other, and probably is explained by the stiff compact soil causing waterlogging during the wettest months. All the main crops are grown, cassava and sweet potatoes being plentiful and so ensuring the area against famine. Eleusine, sorghums, and maize

are the main cereals, and sesame and cow peas are widely grown. Groundnuts are grown on a very small scale and bulrush millet not at all. The good white Ndola sorghum is grown in the west of the area and is spreading eastwards, but elsewhere the dura varieties are poor, being grown on the one-year system explained in Chapter XVI. The type of ground-nut grown in the drier sandier areas to the east is the Bari spreading type, but this is being replaced by the more productive Zande bunch type. An excellent type of lima bean (Dugwe in Kakwa) is grown on stakes around

FIG. 388. Baka tribesman, south of Maridi. Grain drying on stand and selected heads for seed wrapped in bundle carried by him (*photo J. F. E. Bloss*).

all the houses. It probably came from Uganda in the first place and is spreading rapidly to other tribes, all of whom think highly of it. Pigeon peas are grown to a very limited extent. Another characteristic crop of this area, and grown to a less extent elsewhere throughout the province, is 'kino' (*Hyptis spicigera* Lam.), which produces a small oil-seed used like sesame. Mangoes, bananas, pawpaws, guavas, citrus, and oil palms are all grown. No permanent money crop has yet been established. Chillies, bees-wax, honey, and surpluses of other crops are exported. Cotton and robusta coffee have been grown but are not established. A little 'lulu' oil (shea butter) is produced.

Kagulu agricultural experiment station is situated near Yei. This station, since being taken over from the Belgians, has been used for

agricultural and forestry investigations. Experimental areas of various timber trees and plantation crops have been running for many years, and introductions of field, plantation, and timber crops have been made from time to time. There are citrus and other fruit gardens producing up to 50,000 dozen fruit per year. Field-crop trials are also conducted. Kagulu serves the community by providing grafted fruit-trees and seedlings of a variety of plants. At present Kagulu is being used as a centre for training native agricultural staff.

FIG. 389. Sugar is not plentiful in Equatoria Province as costs of distribution are high. Honey is the local substitute and is chiefly obtained by fixing hives in trees as shown in this photo (*photo J. F. E. Bloss*).

Certain areas on the east bank of the river Nile bear a close resemblance to the Yei area. They are the outer foothills of the Acholi Hills and the southern Luluba Hills inhabited by Acholi and Luluba tribes respectively. The soils fall into the same groups in the red loam catena, and the vegetation is a grass woodland type very similar to that of the Yei area. Crops and agricultural practices are similar to those in Yei area, though root crops and fruit-trees are scarce, as they are everywhere on the east bank. Sweet potatoes were recently introduced and are now grown in considerable quantities. Besides the one-year sorghums which are grown there, two good varieties, Lodoker and Zöri, are grown in lighter and drier areas. Sesame is one of the main crops of the Acholi area. Until 1941, when Torit ginnery was closed, American cotton was grown in these areas.

FIG. 390. Shifting cultivation is sound agricultural practice. This is a first year's crop of dura grown by a Baka household near Maridi. Mud huts on right and unfinished grain-stores on left (*photo J. F. E. Bloss*).

FIG. 391. Baka household, near Maridi. Crops include bananas, cassava, pineapples, sweet potatoes. Grain is drying on stands amongst houses (*photo J. F. E. Bloss*).

The Predominantly Sandy and Sandy Loam Areas

For areas so distant from each other and containing such a diversity of tribes the three areas grouped together here are remarkably similar. They have similar types of soil and vegetation and a similar rainfall; it will be seen from the map that they lie along the line of the isohyets. Agricultural practices and crops are also markedly similar. In general a larger area of crops is sown than in Zande or Yei districts, as results are less reliable and as there is only one sowing a year. Bulrush millet and tall open types of sorghum taking about six months to mature are the characteristic cereal crops, and large quantities of ground-nuts and sesame are grown according to the nature of the soil.

The Area on the Fringe of the Ironstone Plateau

Between the ironstone plateau and the lower lands ('toich' or river) there is a strip of land varying from a few yards to many miles wide on which the soils are deeper than on the plateau proper. The soils of this area fall into groups 2 and 3 of the 'toich' catena. They are mostly grey sandy soils with some redder heavier ones, and though not rich, are easy to work and so valued by the natives. They have little humus, and if their absorptive capacity was not high they would be easily erodable. The climate is drier and the vegetation of a drier type than in the Zande and Yei areas. The mean annual rainfall at Amadi is given as 1,251 mm. (49 in.). This area forms a fringe of varying width to the north and east of the ironstone plateau. In the north it is cultivated by Jur, Bongo, some Dinka, especially in Lakes district, and other tribes, and to the east by the Moru, Mandari, and Nyangwara. Only the Dinka living near this area have their cultivations in it, and usually, though not always or at all seasons, have their cattle in the neighbouring 'toich' lands. Some of the country is open and free from tsetse and cattle are kept by Dinka, Mandari, Nyangwara, and Moru, the last having only a few. Though the area stretches for a long distance and contains a variety of tribes, the agricultural practices throughout are very similar. Generally only one crop is taken and sowing of most crops is done early in the rains, though where rainfall is heavier the system may be modified accordingly. The main cereal crops are dura and dukhn. Cassava, sweet potatoes, and yams are grown to a limited extent, sesame in large quantities on the red heavier soils, and ground-nuts in large quantities on the lighter soils, especially in Nyangwara and Mandari areas. Green gram beans which do better on sandy soils are grown in preference to cowpea. Two sorghums (Zöri and Lodoker in Bari) are grown throughout the whole area, Zöri having a slightly longer growing-season and requiring slightly better conditions than Lodoker. They are sown in March or April and harvested about November. The Dinka sorghum Mabior is of the same type as the other two and is extensively grown in the northern parts. Eleusine is grown where conditions are wetter. The spreading type of ground-nut is grown in drier parts and a large podded two-seeded type (called Bambura in Moru) is grown by Moru and Jur. The shea-butter tree is common in this belt and is used as a source of oil. No commercial crop has been

developed, but there is usually a surplus of grain, sesame, or groundnuts for sale.

The Predominantly Sandy Areas of the East Bank and Central District

The central Latuka district and much of the Bari country on both east and west banks of the river Nile are areas of rather low and irregular

FIG. 392. Mahogany tree, probably a relict from a close forest. Note size compared with people on road (*photo J. F. E. Bloss*).

rainfall with the drier types of grass woodland. These are hilly areas with many small hills of basement complex, which can be seen on the map from Torit west as far as Loka and Moru district. On the east side the soils are sandy and correspond with nos. 2 and 3 of the alkaline catena. Pockets of heavier and richer soils are found in the depressions, and in the larger of these this may develop into cracking clay, e.g. on the river Kudo and in the plains to the north, which corresponds with no. 4 in the alkaline catena. Rainfall is a factor of major importance in these areas. The mean annual rainfall at Torit is given as 987 mm. (39 in.), but this

is liable to great variation and irregularity. Where there is a slope, run-off and erosion are severe. The depressions are thus better provided with ground water and wherever possible are used for cultivation. Cattle exist in varying numbers throughout the area. The cropping system in this area is similar to the last, the same sorghums Lodoker and Zöri being used, and bulrush millet and ground-nuts being characteristic crops. Root crops and fruit-trees are conspicuously absent and the area is liable to famine. The tribes inhabiting this area are Latuka, Bari, and Madi.

American cotton has been grown as a cash crop to the east of the river and has been ginned in Torit and Shukoli ginneries. The less sandy soils in the depressions are of course most suitable for cotton. Though cotton was produced in areas other than the one being described, details of cotton production in all the Torit and Shukoli ginnery areas are given in the following tables. Shukoli ginnery ginned Opari and Kajo Kaji cotton till 1936 when it was closed. Thereafter Opari cotton was ginned at Torit and for a time cotton growing at Kajo Kaji virtually stopped.

I. *Seed Cotton Production in Torit and Shukoli (Opari and Kajo Kaji) Ginnery Areas up to 1936*

Area	*Total production 1926–36 (small kantars)*	*No. of feddans Average 1926–36*	*Annual yield Average 1926–36 (small kantars)*	*Yield per feddan Average 1926–36 (small kantars)*	*Price per kantar Average 1926–36*
Torit	82,934	4,607	8,293	1·8	36 P.T.
Opari	36,506	1,304	3,650	2·8	36 P.T.
Kajo Kaji	22,481	1,183	2,248	1·9	

II. *Seed Cotton Production in Torit (Torit and Opari) Ginnery Area 1936–40*

Total production 1936–40 (small kantars)	*No. of feddans*		*Annual yield (small kantars)*		*Yield per feddan (small kantars)*		*Price per kantar*	
	Average 1936–40	*1939–40*	*Average 1936–40*	*1939–40*	*Average 1936–40*	*1939–40*	*Average 1936–40*	*1939–40*
86,263	12,430	8,510	21,566	8,844	1·7	1·0	25¼ P.T.	23 P.T.

Cotton-growing in this area has always been more speculative than in Maridi, but given good soil, a good season, and careful cultivation good yields are obtained. The variety grown was XA129, and this was in process of being changed to SP84 when cotton-growing was stopped as a war measure. Cotton variety trials are still being continued in the Luluba Hills and were conducted for many years at Opari. Pink bollworm, jassids, Helopeltis, stainers, and lygus are the chief pests on the east bank, and blackarm is the only disease causing serious loss.

In the Madi country, south of the central Latuka country, in the southern Bari areas, and the hilly regions between Juba, Loka, and Amadi there is a higher but still irregular rainfall. The country is hilly, and run-

off and erosion are severe. The soils probably belong to nos. 1–2 of the red loam catena or are intermediate between it and the no. 2 group of the alkaline catena. Some of the soils are red stony loams, some sandy, and in the depressions there are pockets of fairly good soil. Eleusine and sesame are characteristic crops of the redder heavier soils, and bulrush millet and ground-nuts of the sandy ones. Cotton was grown in the Madi area, but did not usually yield well. Madi area has long been considered a famine area and sweet potatoes were introduced and are now extensively grown. The Madi use the system of late sowing characteristic of Yei, and it seems possible that if they changed to that of sowing their main crops in April and May they might improve their position. They are reputedly very lazy and improvident.

Areas of the Western District

The populated areas north of Tembura and in the Western district west of Wau lie to the east of the Nile Congo divide, between it and the ironstone plateau. The country is hilly, the few more prominent outcrops being of schists and gneisses, and the lower and commoner ones of ironstone. Rainfall is not as high or as evenly distributed, and the woodlands though fairly dense are not as dense as nearer the watershed. Erosion is fairly severe, and the characteristic series of stony soils, sandy soils, and richer, better-watered soils in the depressions is seen. These belong to groups 2 and 3 of the ironstone catena, being differentiated from the Zande area soils by having less humus, as a result of less rainfall and hotter fires due to more grass. The population in this area is confined to the roads and often has nothing but poor ridge soils to cultivate. The position is being altered and already some good valley areas are under cultivation. The country is all tsetse country, and no cattle are kept, though in parts it is free enough to allow grazing in the dry season. The area is thinly populated by Zande, Balanda, and the miscellaneous tribes west of Wau. Most of the common crops are grown, cassava and sweet potatoes being present in fair quantities. Fruit is not plentiful. Crop failure as a result of poor or irregular rains occurs, though it would not happen were the better and moister valley soils used. In the Abu Satta (gneissose) Hills a wild *Hyparrhenia* is found with a large well-filled seed and is used by the Balanda of this district as a cereal. Surplus sesame is exported as seed or oil, but the main exports are chillies, honey, and bees-wax. The remoteness of this area and the poorness of the soils on which much of the population now live make it of little agricultural importance at present.

Areas of Apron Cultivation

Areas of apron cultivation are small in extent but important where they occur. Apron cultivations consist of cultivations made round the base or apron of hills, and occur round the precipitous northerly hill-groups on the east bank, viz. northern Luluba Hills, Liria, Lowe, Lafit, and Lafon. The soils round the bases of these hills are usually rich black soils belonging to groups 3 and 4 of the alkaline catena and receive much ground moisture from the run-off of the hills. It is this last which makes them of special value in the dry areas where they occur. The tribes occupying

FIG. 393. Zande sorting rubber extracted from *Landolphia* vine. Sources Yubo. The latex is coagulated by rubbing on the skin and subsequently rolling into rope-like strands (*photo J. F. E. Bloss*).

northern Luluba, Liria, Lowe, and Lafit are all closely related and are of Oxoriuk extraction. These people live in villages clustered round the bases of the hills. In addition to the apron cultivation a little crude terracing is done in these areas, on which crops are grown. Sorghum is the most important crop of the apron area, and some excellent varieties are grown, e.g. Naitein of the Lafon. Cotton has been successfully grown on a number of these aprons. In wetter areas other crops may be grown away

FIG. 394. Apron cultivation and settlement at Liria.

from the aprons. Cattle are of importance in all these areas, having grass plains near to the villages for grazing.

Riverain Areas

Riverain areas occur on the river banks, though extensively only on the flood plains along the Bahr el Jebel and Bahr el Ghazal and its tributaries. The flood plains are of rich alluvial soils, falling into group 4 of the 'toich' catena. The flood plains of the Bahr el Jebel and of the Bahr el Ghazal river system differ from each other. In the case of the Bahr el Ghazal, its seasonal tributaries cause more or less continuous flooding from about August till November, after which the plains dry out completely and remain dry for the rest of the dry season. The main grass on these 'toich' plains is *Hyparrhenia* spp. with other excellent grazing grasses such as species of *Paspalum*, *Brachiaria*, *Sporobolus*, and *Oryza*. Bahr el Jebel varies little in level, and actual floods over the grass plains are infrequent and of short duration. The permanent nature of the river maintains a high water-table in the grass plains, and there is in consequence an association of perennial grasses such as *Phragmites mauritianus* Kunth., the reed, elephant grass, Guinea grass, and wild sorghums. *Hyparrhenia rufa* Stapf is common some distance from the river. Where

the water-table seldom falls below ground level there are papyrus swamps with *Vossia cuspidata* Griff. and *Echinochloa pyramidalis* Hitchcock and Chase. These are found on the lower levels along the Bahr el Jebel and on the Bahr el Ghazal, where its level is maintained by the backwash of the Bahr el Jebel.

The Flood Plains of the Bahr el Ghazal and its Tributaries

The Bahr el Ghazal flood plains stretch from west of Aweil to north of Yirrol and southwards in fragments along the main tributary rivers. The

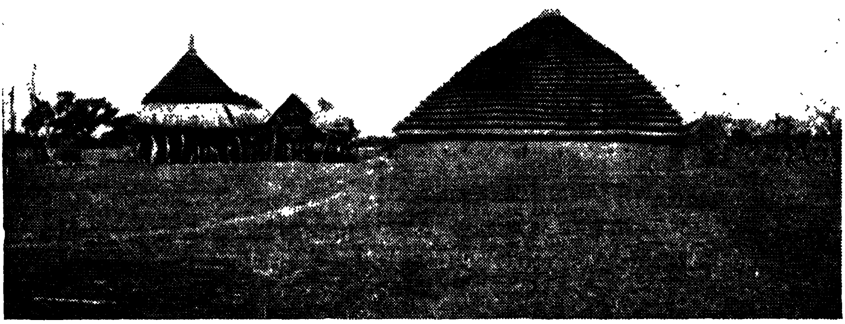


FIG. 395. Dinka homestead with large cowshed 'luak' (*photo H. Ferguson*).

vegetation is pure grass except where there are islands of higher land on which trees may grow. North-west of Aweil there is extensive low-lying woodland which provides both grazing and agricultural land, though it may flood with rain-water. The mean annual rainfall at Aweil is 1,034 mm. (41 in.), at Rumbek 1,064 mm. (42 in.), and at Yirrol 1,000 mm. (39 in.). The wet season lasts from April till September, but rains are sometimes unreliable. The pastures of the plains themselves depend on flood water brought from the south, but the cultivation areas being on higher ground depend on the local rainfall. This area is of great importance both as a grazing and as an agricultural area, and though as yet unexploited its potentialities for livestock and crop production are great. It is thickly populated by several groups of the Dinka tribe, each group having slightly different systems of crop and animal husbandry.

Crops are grown on the edges of the 'toich' lands or on the higher ground in these lands. Sorghum is by far the most extensively grown crop, the excellent variety Mabior being commonest and the quick maturing variety Nyang Jang (which can be harvested before the floods) next in importance. Bulrush millet, sesame, cowpeas, green gram beans, and ground-nuts are grown, the proportions depending on the nature of the

soil. All crops are sown with the early rains, sometimes before, and two crops per year are impossible. In years of good rainfall there is a large surplus of sorghums, sesame, cow peas, and ground-nuts available, but in years of poor rainfall famine conditions may occur. When sesame is available oil is manufactured by bull press 'asara' by traders in Wau, Rumbek, Yirrol, and Aweil. There is no fruit, and no root crops except for a few yams, and the Dinka are rather reluctant to introduce these. Shifting cultivation is practised only on the soils bordering the ironstone; elsewhere crops are grown every year on the same land. Fertility is main-

FIG. 396. Dinka cattle camp ('wot') (*photo H. Ferguson*).

tained by tethering livestock on the cultivation area before sowing and sometimes after harvest, and by the termite method described in Chapter XV. These practices are most highly developed in the Aweil district, where high land for cultivating is scarce.[1]

The grass plains provide most excellent grazing for the large herds of cattle owned by the Dinka. Good pasture is obtained all the year round by grazing the cattle in the rains and flood season on the higher ground near the houses and in the woodlands, and in the dry season by grazing them near the rivers, and by burning to encourage a growth of fresh young grass. Nearly all the time and interest of the Dinkas are taken up with their cattle, and they are excellent herdsmen. Without entering into their interesting practices, it may be stated that their knowledge of animal husbandry is sound, and that their herds are carefully looked after. The cattle vary a great deal in size and conformation, but in general are of a very good beef type. They are slightly humped, usually of medium size, and with long horns. The cattle are largest towards the east, and smallest towards the west of the area, but over all are smaller than White Nile

[1] 'The Western Dinkas, their Land and their Agriculture', by Stubbs and Morison. *Sudan Notes and Records*, vol. xxi, Pt. 2, 1938.

cattle and larger than Uganda cattle.[1] Castration is practised, but no strict method of selection is followed. Breeding bulls are generally of good pedigree and are chosen for such qualities as shape of horn and colouring, rather than for utilitarian qualities. Sometimes the best bulls are castrated to make them grow larger (negative selection), and be special pet or 'song' bulls. Except in the eastern area, the Dinka are reluctant to sell their cattle, but under the stress of war conditions a small export of bulls and bullocks from all Dinka districts, and a small dried-meat factory at Tonj, have been started. The dried meat from Tonj factory

FIG. 397. Dinka cattle at dry season camp near Tonj (*photo H. Ferguson*).

can be retailed at 2 P.T. to 2½ P.T. per rottle in the meatless areas of the south-west and it is already apparent, that, given cash in these areas, they will form an ever-growing market for this product. There is a considerable export of good hides from Dinka areas. The agricultural station serving these areas is at Tonj, where a small experimental farm and a herd of beef cattle for breeding purposes have been established. In addition to their cattle the Dinka own a good breed of sheep of special value as milk producers.

A few of the Dinkas are without cattle, some near Rumbek having lost theirs by the encroachment of fly in their woodland grazing, and others—the Thain Dinka—appear never to have had cattle and live largely on a diet of fish and hippopotamus meat.

The Valley of the Bahr el Jebel

The valley of the Bahr el Jebel north of Juba consists of flood plains

[1] Ankole cattle are an exception to this general statement and are probably related to the long-horned Dinka cattle.—*Editor.*

which are less extensive than those of the Bahr el Ghazal and, farther north, of papyrus swamps. Behind these river flats and swamps on both banks there is very sandy country with open acacia scrub and broad-leaved woodland. Agriculture is of little importance in this area, though the flood plains have possibilities. At present the flood plains are used only for banana gardens and off-season crops of maize and eleusine, which are grown along the levee of the river bank. Their more extensive use is avoided by the natives apparently on account of the possibility of flooding. The areas most used for cultivations are the depressions in the sandy area

FIG. 398. Dinka 'Song' bull (*photo H. Ferguson*).

behind the flood plains. These have better soil and water conditions, and are often protected by heavy woodland. The common crops are grown away from the river, ground-nuts and sorghum sometimes being surplus to requirements. The Bari and Mandari who inhabit this strip own herds of cattle which are grazed on the sandy inland areas in the rains and on the riverain areas in the dry season. They are smaller than the Dinka cattle and are of a dairy rather than a meat type. The manure is not much used and is often allowed to accumulate in the folds ('zarība') in which these cattle are kept. It is used, however, for tobacco, pumpkins, and any crops grown near the houses.

The Dry Eastern Area

In the regions of low rainfall at Kapoeta and to the east of it the country is more suited for grazing than for agriculture. In fact, sorghum is practically the only crop, a good white variety being grown. The soil on the plains is all grey cracking clay belonging to group 4 of the alkaline catena. These plains are inhabited by the Toposa, who own many cattle, sheep, and donkeys. The sheep are of a very good large fat-tailed type

FIG. 399. Typical stream, Zande country. Used for bathing, washing, beer-making, preparing cassava, &c. Bilharzia and ankylostoma are highly endemic in consequence (*photo J. F. E. Bloss*).

which do well on the dry conditions of this area. The Toposa are semi-nomadic, having to seek pasture wherever it can be found.

In the eastern district there are also the Boya and Didinga hill areas inhabited by the Longarim and Didinga tribes. These tribes are pastoralists and agriculturists, grazing their flocks and growing their crops often on steep hill-sides. The hill-sides receive a better rainfall than the plains and so are better fitted to grow a variety of crops.

FIG. 400. Game is scarce in meat-hungry tsetse areas of Equatoria Province, but small animals are assiduously hunted. A Zande hunter is here seen with his net (*photo J. F. E. Bloss*).

The Kajo Kaji Area

Here, instead of the grass woodland characteristic of most of Equatoria, there is some treeless downland which offers good grazing for a fair live-stock population. Kajo Kaji is the only place in Equatoria where cattle have been used for ploughing by the natives. A few of the inhabitants have ploughs, but ploughing is not being encouraged till such time as it can be accompanied by anti-erosion measures. Since the closing of Shukoli ginnery in 1936 the small amount of cotton grown in Kajo Kaji has been purchased by a Uganda ginnery.

THE AGRICULTURAL PROBLEMS AND DEVELOPMENT OF EQUATORIA

As will be seen from the foregoing descriptions of agriculture in Equatoria Province, its agricultural problems are the same as those of other similar tropical countries: the maintenance of soil fertility, the prevention of

erosion, the improvement of crops and livestock, and the combating of the pests and diseases affecting them. As in other remote and undeveloped regions agriculture has to face the task of providing an adequate and balanced food-supply without the help of imports, and, as in regions without other exploitable resources, it has to be the basis of the economic and social development of the community.

Prior to the battle of Omdurman, in 1898, organized slave-raiding under the Egyptian and Dervish régimes inflicted terrible hardships on most of

FIG. 401. *Xanthosoma* is a useful food for wet situations in Equatoria Province. It may harbour Aedes or yellow fever mosquitoes (*photo J. F. E. Bloss*).

the tribes in Equatoria—materially by the immense reductions in human and cattle populations, and morally by the breaking of their spirit and the disintegration of their tribal organization. The healing of these wounds was the first call on the present administration, and its first 40 years have brought back security, self-respect, and a degree of material well-being to the natives. This has been achieved by the development of law and order under a conscientious and sympathetic body of administrators, the improvement of communications and trade, the improvement of health through the magnificent efforts of the Medical Department, and the establishment of educational and other services.

During this period agricultural development has been devoted mainly to the improvement of food supplies. To prevent famine, locust- and drought-resistant crops such as cassava and sweet potatoes have been encouraged, and to provide a more balanced diet new crops such as mango,

oil palm, and soya beans have been introduced. At the same time the Agricultural Department has been investigating and finding solutions of its technical problems, and accumulating information and experience about indigenous and new crops. Some of the more important results of these investigations are reported in Chapter XX. Preliminary attempts to establish cash crops were also made during this period, and American Upland cotton met with a limited amount of success. The problem of providing suitable cash crops for Equatoria Province is not entirely an

FIG. 402. Sesame is an important source of vegetable fat in Equatoria Province. Here the crop is being gathered by the lepers at Li Rangu (*photo J. F. E. Bloss*).

agricultural one, as many saleable commodities can grow in most parts of the Province. The long and expensive transport to the nearest seaport cuts out export of most products, and lack of local animal transport, coupled with the absence of indigenous or organized native markets, is a formidable obstacle to other crops which might be grown.

In 1935 it was recognized that the time had come to take stock of the position with a view to finding out how the final social emergence of the peoples of Equatoria might be brought about. With this end in view Dr. J. G. Myers was appointed in 1937 to make an ecological survey of southern Equatoria. The scope of his work was gradually extended so that, when he met his untimely death in a road accident in 1942, he had completed the ground-work of a survey covering practically the whole province. This work is discussed in some detail in Chapter XX, commencing on p. 587.

During the war the shortage of staff and the difficulty of selling American cotton made it necessary to curtail instead of extend the growing

of cotton in the Province, and to hold up the installation of oil-crushing plant that had been authorized. Serious plans for the economic and social development of the province had to be postponed, but during this waiting period a scheme for training native agricultural staff was started at Kagulu and maintained in the certainty that a development scheme would eventually be put forward.

In 1944 conditions appeared to be propitious for taking the next step, and Tothill put forward a scheme which he called 'An Experiment in the Social Emergence of a Remote Area'. The Zande area was chosen for the experiment, and the scheme aims at nothing less than the complete social emergence and the social and economic stability of the Zande people.

The inherent difficulties in implementing a scheme of this sort were recognized, and it was apparent from Myers's work and the accumulated experience of all who had worked in and knew the province that definite measures would have to be taken to put these right before full emancipation could be expected to occur. The present resources of the province were so small and undeveloped that the cost of education and other services could not be met from the revenues of the province, and the normal aspirations of a progressing people could not be allowed to develop. The fundamental problem of remoteness which has already been mentioned resulted in low returns to the natives for local produce coupled with high cost of imported goods, and hence an extremely low purchasing power for the native. Under these circumstances few natives considered their potential reward worth the extra effort required to increase their output, and many remained too poor to buy such dietary essentials as meat and salt, much less the cheapest and most essential trade goods. Though in itself one of the reasons for lack of shops, this state of affairs was in part due to the extremely poor shopping facilities available. Badly balanced diet and chronic infection with internal parasites were also adverse factors.

In order to overcome these difficulties the Zande scheme includes the establishment of certain agricultural industries, the expansion of education to attain universal literacy in 30 years, and the proportional stepping up of medical and other services. As the key industry it provides for the growing of cotton, ginning it, the spinning of the lint at a mill to be established within the area, and the sale of the cloth within the Sudan to replace in part the 1,500 tons annually imported. Cotton growing would be developed as an integral part of an improved native agricultural system designed so that each householder produced on his own farm adequate food for his family and sufficient cotton to bring in a serviceable income. Two advantages should accrue from manufacturing the cotton locally. Firstly, the very substantial savings in transport and carrying charges will enable an attractive price to be paid to the cultivator. Secondly, cotton-piece goods which are amongst the most essential and attractive trade goods can be made available at a much cheaper rate than the imported article.

The Zande scheme also embraces a number of self-sufficiency measures rendered necessary by the high cost of imported goods, and offering the same advantages as the cotton project. Provision is made for

FIG. 403. An agricultural land resettlement problem has arisen in parts of Equatoria Province due to the discovery that a local species of blackfly is the vector of a disease causing blindness. The fly *Simulium damnosum* breeds on the stones in the waters of cataracts and travels many miles by wind. It is necessary to move populations away from *Simulium* areas (*photo J. F. E. Bloss*).

FIG. 404. There is an acute shortage of meat in the Zande diet. Fish-baskets in any kind of rapids are always set and catch many kinds of fish (*photo J. F. E. Bloss*).

FIG. 405. Zande people fishing in a dammed-up stream. Any source of fish or meat is eagerly sought irrespective of quality (*photo J. F. E. Bloss*).

FIG. 406. Women catching small fish among the reeds in meat-hungry Yambio district (*photo J. F. E. Bloss*).

FIG. 407. To bring civilization to Zandeland the distribution of trade goods needs to be greatly extended. Here is a roadside shop with salt on the table and chillies in the bowl for sale. Note the carved bowl and the ubiquitous petrol-tin (*photo J. F. E. Bloss*).

FIG. 408. Zande with freshly cut bark cloth. The man is wearing a skirt made from this material. Spear grass (*Imperata cylindrica*) in background (*photo J. F. E. Bloss*).

the production of soap from cotton seed and locally produced palm oil, for the growing and curing of robusta coffee, and the growing of sugar and manufacture of jaggery. These crops, like the cotton, would ultimately be owned by the natives themselves and grown by them in conjunction with properly run holdings for production of food. Another project designed to utilize local resources is the establishment of a saw-mill to produce timber to replace imported building material. Other local materials and products would be used as far as possible and further possibilities investigated, e.g. the use of charcoal as a source of power. Some commodities not produced in the area, for example meat, would be available from adjacent areas in exchange for produce from the Zande area, and this small local trade would add to the revenue obtained from the export of cotton-piece goods to other parts of the Sudan.

Another essential part of the scheme is the provision of controlled shops throughout the experimental area to deal with local raw and manufactured products and to supply attractive and essential imported goods at the lowest possible rate, thus permitting the standard of living to rise.

It is contemplated that the scheme will be controlled by a board who will co-operate with the local authorities, and in an increasing degree with the local inhabitants themselves, whose education and experience will in the course of time fit them for an increasing share in the responsibilities of the scheme.

The Zande area was chosen by Tothill for the experiment because it was so remote from overseas markets that there was no prospect of achieving social emergence on the basis of exports to places beyond the Sudan, and the good agricultural climate, some good soil, and a reasonably dense population ensured that the raw materials required could be produced satisfactorily. If the experiment is a success it will mean the emergence of a happy, prosperous, literate peasant community, able, by its prosperity to obtain, and through its education to enjoy, the good things that civilization can bring to 'the Gentle Savage'. Should the experiment begin to succeed, the principles involved could be extended to other parts of Equatoria and the Sudan, and this might well happen before the 30-year period has elapsed. In the meantime the agricultural and other services, depleted during the second world war, are being brought up to full strength and specific developments and general welfare are again progressing.

The Zande experiment has been approved by the Sudan Government in principle and details are now being worked out.

FINIS

'Look at the end of work, contrast
The petty done, the undone vast.'

ROBERT BROWNING.

APPENDIX

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APPENDIX TO CHAPTER XIX

BIBLIOGRAPHY OF PUBLICATIONS ON AGRICULTURAL RESEARCH IN THE SUDAN

Compiled by the late FRANK CROWTHER

This bibliography comprises the publications of the research staff of the Sudan Government and those of visitors who have done research in the Sudan. Before 1931 the Annual Reports of the research sections were either published independently or included, often in summary form, in those of the Gordon Memorial College or of the Department of Agriculture and Forests. Usually the chemical and entomological work was included in the former and the botanical work in the latter. Details are included under the separate headings below. The combined reports of all sections for seasons 1926–7, 1927–8, and 1928–9 were printed under the title *Agricultural Research Work in the Sudan*; and those for the two following seasons, 1929–30 and 1930–1, were collected but never printed.

Since 1931 the annual reports of most of the research sections, including all which work in the Gezira Scheme, have been bound together and published as the annual reports of:

(*a*) Gezira Agricultural Research Service (1931–5)
(*b*) Agricultural Research Service (1935–8)
(*c*) Agricultural Research Institute (1938–44)
(*d*) Research Division, Department of Agriculture and Forests (from 1944).

The reports for seasons 1931–2 to 1934–5 were duplicated for distribution and those for 1935–6 to 1937–8 were printed. Later reports, because of the war, at present exist only in typescript.

In this bibliography individual reports and papers are grouped under subject headings as follows:

(A) Agriculture
(B) Botany and Plant Pathology
(C) Entomology
(D) Plant Breeding
(E) Plant Introduction
(F) Plant Physiology
(G) Soil Research.

In Chapter XX much of the experimental work is credited to the individual investigator, but often the only account of the work so far published has been in an annual report. To facilitate reference, therefore, in this bibliography, footnotes are appended which name the investigators mentioned in Chapter XX whose work is described in the reports indicated.

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2. *Department of Agriculture and Forests*: (*a*) from 1911 to 1913, printed in 'Reports on the Finance, Administration, and Condition of the Sudan', the 1911 report including that of the Central Experimental Farm, Shambat, and those of 1912 and 1913 giving detailed accounts of the first results with irrigation in the Gezira, at the Gezira Agricultural Experimental Station, Taiyiba; (*b*) from 1914 issued separately with, from 1918–19 to 1930–1 but excepting 1926–7 to 1928–9, reports of the Gezira Research Farm included as appendixes. (1914 to 1925–6 typewritten only; 1929–30 and 1930–1 duplicated.)
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(*c*) *Other Publications*

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[1] Including work, described in Chapter XX, on irrigated areas by V. P. Walley, E. Mackinnon, E. R. John, and W. A. Porter, and from 1935–6, on rain-areas by R. T. Paterson, W. A. Porter, L. E. James, J. W. Hewison, E. S. Colman, A. P. Milne, and H. Ferguson. For other work on husbandry see under headings 'Botany and Plant Pathology' and 'Plant Physiology'.

WALLEY, V. P. (1925) 'Demonstration of Some of the Gezira Research Farm Plots'. *Rep. Meeting Sudan Gezira, Dec. 1925, Well. Trop. Res. Lab.*, p. 36.

—— (1927) 'Cotton Growing at the Gezira Research Farm, with a Brief Account of Some of the Experimental Plots'. *Rep. Meeting Khartoum, Jan. 1927*, pp. 1–14.

—— (1928) 'Note on the Third Meeting and Inspection of Some of the More Important Farm Plots'. *Rep. Meeting G.R. Farm, Dec. 1928*, pp. 3–6.

—— (1936) 'Working Cattle in the Anglo-Egyptian Sudan'. *Emp. Cott. Gr. Rev.* xiii, pp. 294–6.

B. BOTANY AND PLANT PATHOLOGY

(*a*) *Books*

MASSEY, R. E. (1926) *Sudan Grasses.* Bot. Series, Pub. No. 1, Dept. Agric. Forests.

CROWFOOT, G. M. (1928) *Flowering Plants of the Northern and Central Sudan.* Orphans' Press, Leominster.

BROUN, A. F., and MASSEY, R. E. (1929) *Flora of the Sudan.* Sudan Govt. Price P.T. 50.

(*b*) *Annual Reports*[1]

1. The Botanical Section, Shambat, by Government Botanist from 1920 to 1925–6 and of the Botanical Section of the Gezira Research Farm from 1922–3 to 1925–6, included as appendixes to the *Annual Report of the Department of Agriculture and Forests.* (Typewritten only.)
2. The Section of Plant Physiology and Pathology, at Shambat, by Government Botanist, and the Botanical Section of the Gezira Research Farm, printed in *Agricultural Research Work in the Sudan* for 1926–7, 1927–8, and 1928–9. Reports of the Section of Plant Physiology and Pathology for 1928, 1929 (both printed), and 1930 (duplicated) included as appendixes to the *Annual Report of the Department of Agriculture and Forests.*
3. The Section of Botany and Plant Pathology from 1931–2 until 1943–4 included in the annual report of the research organization. (Duplicated from 1931–2 to 1934–5. Printed from 1935–6 to 1937–8. Later years not yet duplicated.)

(*c*) *Other Publications*

BALFOUR, A. (1904) 'Insects and Vegetable Parasites Injurious to Crops'. *First Rep. Well. Res. Lab.*, pp. 40–5.

THEOBALD, F. V. (1906) 'Vegetal Pests'. *Second Rep. Well. Res. Lab.*, pp. 93–7.

[1] Including work, described in Chapter XX, by R. E. Massey, A. R. Lambert, F. W. Andrews, T. W. Clouston, A. S. Boughey, and M. C. Hattersley. For other literature on leaf curl see under 'Entomology'.

MASSEY, R. E. (1921) 'Notes on Some Plant Diseases caused by Fung in the Sudan'. *Sudan Notes and Rec.* iv, pp. 219–24.

—— (1922) '*Helminthosporium* sp. on Wheat and Barley in the Sudan'. *Sudan Notes and Rec.* v, pp. 105–6.

—— (1924) 'Bacterial Disease of Cotton'. *Sudan Notes and Rec.* vii, pp. 123–4.

ARCHIBALD, R. G. (1925) 'Field Demonstration on Black Arm Disease of Cotton with Special Reference to its Epidemiology'. *Rep. Meeting Sudan Gezira, Dec. 1925, Well. Trop. Res. Lab.*, pp. 9–14.

MASSEY, R. E. (1927) 'On the Relation of Soil Temperature to Angular Leaf-spot of Cotton'. *Ann. Bot.* xli, pp. 497–506.

ARCHIBALD, R. G. (1927) 'Sulphuric Acid Treatment of Cotton Seed'. *Soil Sc.* xxiii, pp. 1–3.

—— (1927) 'Blackarm Disease of Cotton with Special Reference to the Existence of the Causal Organism, *B. malvacearum*, within the Seed'. *Soil Sc.* xxiii, pp. 4–9.

—— (1927) 'The Castor Oil Plant. Black Rot in the Gezira'. *Trop. Agric.* iv, pp. 124–5.

MASSEY, R. E. (1927) 'Recent Studies in Plant Physiology and Pathology'. *Rep. Meeting Khartoum, Jan. 1927, Well. Trop. Res. Lab.*, pp. 15–33.

—— (1928) 'On the Development of *Pseudomonas malvacearum* E. F. Smith, within the Cotton Plant'. *Rep. Meeting G.R. Farm, Dec. 1928, Well. Trop. Res. Lab.*, pp. 45–65.

ARCHIBALD, R. G. (1928) 'Further Investigations on Black Arm Disease of Cotton'. *Agric. Res. Work in Sudan, Rep. Season 1927–8, Sudan Govt.*, pp. 127–33.

MASSEY, R. E. (1929) 'Black Arm Disease of Cotton'. *Emp. Cott. Gr. Rev.* vi, pp. 124–53.

KENCHINGTON, F. E. (1929) 'Note on Adventitious Bud Formation in Cotton'. *Emp. Cott. Gr. Rev.* vi, pp. 246–7.

MASSEY, R. E., and HATTERSLEY, M. C. (1929) 'Note on Black Arm Disease of Cotton'. *Emp. Cott. Gr. Rev.* vi, pp. 248–9.

—— (1930) 'Studies on Black Arm Disease of Cotton'. *Emp. Cott. Gr. Rev.* vii, pp. 185–95.

—— (1931) 'Studies on Black Arm Disease of Cotton. II'. *Emp. Cott. Gr. Rev.* viii, pp. 187–213.

—— and ANDREWS, F. W. (1932) 'The Leaf Curl Disease of Cotton in the Sudan'. *Emp. Cott. Gr. Rev.* ix, pp. 32–45.

—— (1934) 'Studies on Black Arm Disease of Cotton. III'. *Emp. Cott. Gr. Rev.* xi, pp. 188–93.

—— (1934) 'Angular Leaf Spot and Black Arm of Cotton'. *Emp. Cott. Gr. Corp. Second Conf. on Cott., July 1934*, pp. 175–8.

BAILEY, M. A. (1934) 'Leaf Curl Disease of Cotton in the Sudan'. *Emp. Cott. Gr. Rev.* xi, pp. 280–8.

ANDREWS, F. W. (1936) 'The Effect of Leaf Curl on the Yield of the Cotton Plant'. *Emp. Cott. Gr. Rev.* xi, pp. 287–98.

—— (1936) 'Investigations on Black Arm Disease of Cotton under Field Conditions. I. The Relation of the Incidence and Spread

of Black Arm to Cultural Conditions and Rainfall in the A.-E. Sudan'. *Emp. J. Exp. Agric.* iv, pp. 344–56.

ANDREWS, F. W. (1937) As above, 'II. The Effect of Flooding Infective Cotton Debris'. *Emp. J. Exp. Agric.* v, pp. 204–18.

MASSEY, R. E. (1937) 'Seed Disinfection, with Special Reference to Cotton'. *Emp. Cott. Gr. Rev.* xiv, pp. 301–7.

ANDREWS, F. W. (1938) 'Investigations on Black Arm, &c. III. The Mode of Infection of the Newly Planted Crop'. *Emp. J. Exp. Agric.* vi, pp. 207–18.

—— (1940) 'A Study of Nut Grass (*Cyperus rotundus* Linn.) in the Cotton Soil of the Gezira. I. Maintenance of Life in the Tuber'. *Ann. Bot.*, N.S. vol. iv, pt. 13, pp. 177–194.

—— (1940) 'The Control of Nut Grass in the Sudan Gezira'. *Emp. J. Exp. Agric.* viii, pp. 215–22.

BOUGHEY, A. S. (1942) List of Economic Plant Diseases in the A.-E. Sudan. *Dept. Agric. Forests, Sudan Govt.*

—— (1942) 'Cotton-seed Disinfection in War-time'. *Nature*, cxlix, pp. 50–1.

—— (1944) 'Physiological Cotton Wilt in the Sudan Gezira'. *Ann. Appl. Biol.* xxxi, pp. 12–18.

ANDREWS, F. W. (1945) 'Water Plants in the Gezira Canals. A study of Aquatic Plants and their Control in the Canals of the Gezira Cotton Area (Anglo-Egyptian Sudan).' *Ann. Appl. Biol.* xxxii, pp. 1–14.

—— (1945) 'The Parasitism of *Striga hermonthica* Benth. on *Sorghum* spp. under Irrigation. I. Preliminary Results and the Effect of Heavy and Light Irrigation on *Striga* Attack.' *Ann. Appl. Biol.* xxxii, pp. 193–200.

—— (1945) 'A Study of Nut Grass (*Cyperus rotundus* Linn.) in the Cotton Soil of the Gezira. II. Perpetuation of the Plant by means of Seed.' *Ann. Bot.*, N.S. vol. x, pt. 37, pp. 15–30.

—— (in press) 'The Flora of Erkowit. A. Trees and Shrubs.' *Bull. No. 1, Res. Div., Dept. Agric. Forests.*

C. ENTOMOLOGY

Until 1931 work on crop pests was carried out by the Entomological Section of the Wellcome Tropical Research Laboratories, with headquarters in the Gordon Memorial College, Khartoum. In 1931 the section was split, some of the work remaining in Khartoum and the rest being undertaken by the newly formed Entomological Section of the Gezira Agricultural Research Service stationed at the Gezira Research Farm, Wad Medani, where experimental work had started in 1919. In 1936 the headquarters of the entomological work was transferred to Wad Medani.

(*a*) *Reports*

BALFOUR, A. (1904) 'Insects and Vegetable Parasites Injurious to Crops'. *First Rep. Well. Res. Lab.*, pp. 40–5.

—— (1906) 'Biting and Noxious Insects Other than Mosquitoes'. *Second Rep. Well. Res. Lab.*, pp. 29–50.

THEOBALD, F. V. (1906) 'Vegetal Pests'. *Second Rep. Well. Res. Lab.*, pp. 93–7.

KING, H. H. (1908) 'Report on Economic Entomology'. *Third Rep. Well. Res. Lab.*, pp. 201–49.

—— (1911) 'Report of the Entomology Section'. *Fourth Rep. Well. Trop. Res. Lab.*, vol. B, pp. 95–150.

BUTLER, A. L. (1911) 'The Finches and Weaver Birds of the Sudan, being Notes on the Group containing the Birds Injurious to Grain Crops'. *Fourth Rep. Well. Trop. Res. Lab.*, vol. B, pp. 157–78.

(*b*) *Annual Reports*[1]

1. *Gordon Memorial College*, from 1905 to 1934, including summary reports only.
2. Report of Scientific Research Committee, for 1921, 1922, and 1923.
3. Work of the Entomological Section, included in *Agricultural Research Work in the Sudan* from 1926–7 to 1928–9 (1929–30 and 1930–1 not printed).
4. *Government Entomologist*, for 1926–32, included in list of bulletins below.
5. *Gezira Entomological Section* (later *Entomological Section*) for seasons 1931–2 onwards, included in Annual Report of the research organization. (Duplicated from 1931–2 to 1934–5. Printed from 1935–6 to 1937–8. Later years not yet duplicated.)

(*c*) *Entomological Circulars*

Cir. No.

1. KING, H. H. (1909) *Directions for the Collection of Blood-sucking Insects and Ticks*. Published in English and Arabic.
2. —— (1915) *An Injurious Weed* (*Abutilon graveolens*). Published in English and Arabic.
3. —— (1915) *Dura Asal Fly*. Published in English and Arabic.
4. —— (1917) *The Asal Fly on Dura in Dongola Province*. Published in Arabic.
5. —— (1917) *The Pink Bollworm at Tokar*. Published in Arabic.
6. —— (1918) *The Clothes Beetle* (*Anthrenus vorax*). Published in English and Arabic.
7. —— (1918) *Locusts*. Published in Arabic.

(*d*) *Entomological Bulletins*

Bull. No.

1. KING, H. H. (1914) *Locust Destruction*. Published in English and Arabic.
2. —— (1915) *The Dura Asal Fly* (*Aphis sorghi* Theob.) *in Dongola Province, Anglo-Egyptian Sudan*. Published in English.

[1] Including work, described in Chapter XX, by H. H. King, G. H. Corbett, H. W. Bedford, W. E. Giffard, H. B. Johnston, T. W. Kirkpatrick, F. G. S. Whitfield, W. Ruttledge, J. W. Cowland, W. P. L. Cameron, R. C. Maxwell-Darling, A. P. G. Michelmore, A. H. Wood, and D. J. Lewis.

3. KING, H. H. (1916) *The Migratory Locust* (*Schistocerca peregrina* Oliver) *and its Control.* Published in English.
4. —— (1917) *The Pink Bollworm* (*Gelechia gossypiella* Saunders) *in Anglo-Egyptian Sudan.* Published in English.
5. —— (1917) *The Pink Bollworm* (*Gelechia gossypiella* Saunders) *and Measures for its Control.* Published in English.
6. —— (1917) *The Sudan Cotton Bollworm* (*Diparopsis castanea* Hampson). Published in English.
7. —— (1917) *The Weed Hambuk* (*Abutilon* spp.) *and its Relation to the Cotton Growing Industry in the Anglo-Egyptian Sudan.* Published in English.
8. —— (1918) *Clean Cultivation in its Relation to the Control of Insect Pests.* Published in English.
9. —— (1918) *The Control of Insect Pests of Cotton.* Published in English.
10. —— (1918) *The Pink Bollworm Pectinophora* (*Gelechia*) *gossypiella* Saunders, *at Tokar, Anglo-Egyptian Sudan, during the Season, 1917–18.* Published in English.
11. —— (1920) *A Beehive Designed for the Production of Beewax Suitable for Use by Natives of the Southern Sudan.* Published in English.
12. —— (1921) *The Migratory Locust* (*Schistocerca peregrina* Oliver). Published in English.
13. —— (1921) *Rats and Mice.* Published in English.
14. —— (1921) *Hyaenas.* Published in English.
15. —— (1921) *The Locust.* Published in English and Arabic.
16. —— (1921) *The Fowl Tick* (*Argas persicus* Oken).
17. BEDFORD, H. W. (1921) *The Asal of Cotton and its Causes in the Sudan.*
18. —— (1921) *The Cotton Thrips* (*Heliothrips indicus* Bagnall) *in the Sudan, with a Description of its History and Habits in the Gezira* (*Blue Nile Province*) *and Measures for its Control.*
19. —— *The Pests of Cotton in the Anglo-Egyptian Sudan, with Description of the Damage Caused to the Plan and Measures Recommended for their Control.*
20. KING, H. H. (1923) *The Spanish Sparrow* (*Passer hispaniolensis transcaspicus* Tschusi). *A Pest of Grain Crops in Dongola Province.*
21. —— and GIFFARD, W. E. (1924) *The Control of Pink Bollworm* (*Platyedra gossypiella* Saunders) *in the Sudan.*
22. JOHNSTON, H. B. (1926) *A Further Contribution to our Knowledge of the Bionomics and Control of the Migratory Locust, Schistocerca gregaria* Forsk. (*peregrina* Oliver) *in the Sudan.*
23. KING, H. H. (1926) *The Ticks* (*Ixodoidea*) *of the Sudan.*
24. —— (1927) *Report of the Government Entomologist for the Year 1926.*
25. —— (1928) *Report of the Government Entomologist for the Year 1927.*
26. JOHNSTON, H. B. (1929) *Pink Bollworm* (*Platyedra gossypiella* Saunders) *in the Gezira District of the Sudan in 1927 and 1928.*

27. GIFFARD, W. E. *The Sudan Bollworm* (*Diparopsi castanea* Hampson) *in the Sudan.*
[1]28. WHITFIELD, F. G. S., and CAMERON, W. P. L. (1930) *The Dura Andat Bug.* (*Agonoscelis versicolor* F.).
29. KING, H. H. (1929) *Report of the Government Entomologist for the Year 1928.*
30. —— (1930) *The Desert Locust. Schistocerca gregaria* Forsk.
31. —— (1930) *Report of the Government Entomologist for the Year 1929.*
32. BEDFORD, H. W. (1930) *A Description of the Methods Adopted in the Sudan in the Organization of the Insect Collection and the Systematic Compilation of Records.*
33. Not published.
[1]34. KING, H. H. (1931) *Report of the Government Entomologist for the Year 1930.*
[1]35. —— (1932) *Report of the Government Entomologist for the Year 1931.*
[1]36. —— (1933) *Report of the Government Entomologist for the Year 1932.*

(*e*) *Papers Published in Journals*

1. KING, H. H. (1909) 'A Stem Boring Beetle Attacking Cotton in the Sudan'. *J. Econ. Biol.* iv.
2. —— (1913) 'Note on an Entomological Store-box Suitable for Use in the Tropics'. *Bull. Ent. Res.* iv, p. 85.
3. —— (1913) 'On the Use of Poison in the Control of Locusts in the Anglo-Egyptian Sudan'. *Cairo Sc. J.*, No. 60, vii, pp. 251–4.
4. —— (1915–16) 'Preliminary Notes on the Life-History of *Argas brumpti* Neumann'. *Bull. Ent. Res.* vi, pp. 191–3.
5. CORBETT, G. H. (1920) 'Observations on Cotton Thrips in the Gezira, Blue Nile Province, Sudan in 1918–19'. *Bull. Ent. Res.* xi, pt. 2, pp. 95–100.
6. COTTAM, R. (1922) 'Notes on the Bionomics of an Aphidophagous Fly of the Genus *Leucopis* in the Anglo-Egyptian Sudan'. *Ent. Mon. Mag.*, 3rd Ser., viii, pp. 61–4.
7. —— (1922) 'Observation on the Phyllodromic Cockroach, *Blattella supellectelium* Serv. in Khartoum'. *Ent. Mon. Mag.*, 3rd Ser., viii, pp. 156–8.
8. KING, H. H. (1922) 'Note on the Origin of the Migratory Locust'. *Sudan Notes and Rec.* v, pp. 54–6.
9. —— (1925) 'Notes on Sudan Scorpions'. *Sudan Notes and Rec.* viii, No. 2, pp. 79–84.
10. —— and JOHNSTON, H. B. (1925–6) 'A Simple Form of Distributor for Insecticide Dusts'. *Bull. Ent. Res.* xvi, pp. 175–6.
11. COWLAND, J. W., and RUTTLEDGE, W. (1927) 'Notes on Cotton Stainers (*Dysdercus*) in the Sudan'. *Bull. Ent. Res.* xviii, pp. 159–63.

[1] Duplicated only.

12. KING, H. H. (1928) 'The Pink Bollworm (*Platyedra gossypiella* Saunders) in the Sudan'. *IVth Int. Cong. Ent., Ithaca, 1928*, ii, pp. 90–3.

13. RUTTLEDGE, W. (1928–29) 'Tsetse Fly (*Glossina morsitans*) in the Koalib Hills, Nuba Mountains Province, Sudan'. *Bull. Ent. Res.* xix, 309–16.

14. KING, H. H. (1929) 'A Note on the Use of the Dried Poison Bait against Locusts in the Sudan'. *Bull. Ent. Res.* xx, pp. 99–101.

15. WHITFIELD, F. G. SAREL (1929) 'The Sudan Millet Bug, *Agonoscelis versicolor* F.' *Bull. Ent. Res.* xx, pp. 209–24.

16. BEDFORD, H. W. (1930) 'The Distribution of Tsetse Flies in the Sudan'. *Bull. Ent. Res.* xxi, pp. 413–15.

17. KIRKPATRICK, T. W. (1930) 'Preliminary Note on Leaf Crinkle of Cotton in the Gezira Area, Sudan'. *Bull. Ent. Res.* xxi, pp. 127–37.

18. RUTTLEDGE, W. (1930) 'Notes on *Argas brumpti* (*Acarina*)'. *Bull. Ent. Res.* xxi, p. 273.

19. JOHNSTON, H. B., and MAXWELL-DARLING, R. C. (1931) 'On the Occurrence in the Sudan of *Locusta migratorioides* RCH. & FRM., and its Associated Phases'. *Bull. Ent. Res.* xxii, pp. 399–416.

20. KIRKPATRICK, T. W. (1931) 'Further Studies on the Leaf Curl of Cotton in the Sudan'. *Bull. Ent. Res.* xxii, pp. 323–63.

21. KING, H. H., and RUTTLEDGE, W. (1932) 'On Experiments in the Use of Poison Dusts against Adult *Locusta migratorioides* RCH. & FRM., in the Sudan'. *Bull. Ent. Res.* xxiii, pp. 65–8.

22. WHITFIELD, F. G. SAREL (1935) 'The Bionomics and Control of *Dysdercus* (*Hemiptera*) in the Sudan'. *Bull. Ent. Res.* xxiv, pp. 301–13.

23. WOOD, A. H. (1933) 'Notes on Some Dipterous Parasites of *Schistocerca* and *Locusta* in the Sudan'. *Bull. Ent. Res.* xxiv, pp. 521–30.

24. BEDFORD, H. W. (1934) 'Problems connected with the Control of the Pink Bollworm (*Platyedra gossypiella* Saunders) in the Sudan'. *Emp. Cott. Gr. Corp., Rep. Second Conf.*, pp. 167–75.

25. MAXWELL-DARLING, R. C. (1934) 'The Solitary Phase of *Schistocerca gregaria* Forsk. in N.E. Kordofan (Anglo-Egyptian Sudan)'. *Bull. Ent. Res.* xxv, pp. 63–83.

26. COWLAND, J. W. (1936) 'The Sorghum Midge in the Anglo-Egyptian Sudan'. *Ann. Appl. Biol.* xxiii, pp. 110–13.

27. MAXWELL-DARLING, R. C. (1936) 'A Short Reconnaissance of Northern Darfur (Anglo-Egyptian Sudan) with regard to *Schistocerca gregaria* Forsk.'. *Bull. Ent. Res.* xxvii, pp. 71–6.

28. —— (1936) 'The Outbreak Centres of *Schistocerca gregaria* Forsk. on the Red Sea Coast of the Sudan'. *Bull. Ent. Res.* xxvii, pp. 37–66.

29. —— (1937) 'The Outbreak Areas of the Desert Locust (*Schistocerca gregaria* Forsk.) in Arabia'. *Bull. Ent. Res.* xxviii, pp. 605–18.

(*f*) *Other Miscellaneous Publications*

BEDFORD, H. W. (1925) 'Field Demonstration on the Relation of Insect Pests to Soil Conditions'. *Rep. Meeting Sudan Gezira, Dec. 1925, Well. Trop. Res. Lab.*, pp. 15–17.

JOHNSTON, H. B. (1927) 'On the Study of Parasitic Insects, and their Economic Importance in the Sudan'. *Rep. Meeting Khartoum, Jan. 1927*, Well. Trop. Res. Lab., pp. 35–44.

KING, H. H. (1928) 'Observations on the Work of the Entomology Section in the Gezira during 1928'. *Rep. Meeting G.R. Farm, Dec. 1928, Well. Trop. Res. Lab.*, pp. 26–36.

BAGNALL, R. S., and CAMERON, W. P. L. (1932) 'Description of Two Species of *Hercothrips* Injurious to Cotton in the Sudan and of an Allied Species on Grass'. *Ann. Mag. Nat. Hist.*, 10th Ser., No. 58, pp. 412–19.

BEDFORD, H. W. (1934) 'Problems connected with the Control of the Pink Bollworm in the Sudan'. *Emp. Cott. Gr. Corp., Second Conf. Cott. Gr. Problems, July 1934*, pp. 167–75.

D. PLANT BREEDING

(*a*) *Reports*[1]

1. Earliest references in Bull. No. 1 Central Research Farm (Shambat) Khartoum North, see details under 'Agriculture'.
2. Annual Reports Botanical Section, Shambat, from 1920 to 1924–5 and Botanical Section, Gezira Research Farm, from 1922–3 to 1925–6, included as appendixes to Annual Reports of Department of Agriculture and Forests. (Typewritten only.)
3. Annual Reports of Plant Breeding Section from 1925–6 onwards, published in *Reports* (Later *Progress Reports*) *from Experimental Stations. Emp. Cott. Gr. Corp.*, 1927 onwards. (All printed up to 1943–4 except for season 1939–40.)
4. Annual Reports in 3, above, for 1926–7, 1927–8, and 1928–9 also included in *Agricultural Research Work in the Sudan* for the same seasons.
5. Annual Reports of Plant Breeding Section for 1928, 1929, and 1930, concerning especially crops other than cotton, included as appendixes to *Annual Reports of Department of Agriculture and Forests* (1928 and 1929 printed; 1930 duplicated). Reports from 1931–2 onwards included in those of whole research organization. (Duplicated from 1931–2 to 1934–5. Printed from 1935–6 to 1937–8. Later years not yet duplicated.)
6. Reports on Plant Breeding Extension Work at the Gezira Research Farm for 1931–2 to 1934–5, included in those of the research organization. (Duplicated but not printed.)

[1] Including work, described in Chapter XX, by R. E. Massey, M. A. Bailey, A. R. Lambert, T. Trought, H. E. King, F. E. Kenchington, R. L. Knight, R. R. Anson, and S. H. Evelyn.

(*b*) *Other Publications*

MASSEY, R. E. (1921) 'Note on the Maintenance of Quality of Cotton Grown in the Sudan'. *Sudan Notes and Rec.* iv, pp. 44–5.

BAILEY, M. A. (1926) 'Development of the Cotton Plant in the Gezira'. *Rep. Meeting Sudan Gezira, Dec. 1925, Well. Trop. Res. Lab.*, pp. 29–34.

—— (1929) 'Cotton Variety Testing in the Sudan'. *Rep. Meeting G.R. Farm, Dec. 1928, Well. Trop. Res. Lab.*, pp. 26–36.

—— (1930) 'The Causes of Nep in Cotton'. *Emp. Cott. Gr. Corp. Rep. on Cott. Gr. Problems*, Aug. 1930, pp. 17–39.

—— (1930) 'The Desirability of Interchange of Details of Methods Employed in Measuring Halo-lengths at Different Experiment Stations'. *Emp. Cott. Gr. Corp. Rep. on Conf. on Cott. Gr. Problems*, Aug. 1930, pp. 152–7.

TROUGHT, T., and KING, H. E. (1934) 'Preliminary Testing of New Varieties or Types of Cotton'. *Emp. Cott. Gr. Corp. Rep. on Second Conf. on Cott. Gr. Problems*, July 1934, pp. 51–60.

KNIGHT, R. L. (1935) 'The Effect of Shade on American Cotton'. *Emp. J. Exp. Agric.* iii, pp. 31–40.

—— (1937) Letter *re* 'An Inexpensive Method of Selfing Cotton Flowers'. *Emp. Cott. Gr. Rev.* xiv, p. 231.

TROUGHT, T. (1937) 'Cotton Growing and Breeding in the A.-E. Sudan'. *Emp. Cott. Gr. Rev.* xiv, pp. 197–205.

LAMBERT, A. R. (1938) 'New Sakel Strains in the A.-E. Sudan'. *Emp. Cott. Gr. Rev.* xv, pp. 14–20.

KNIGHT, R. L., and CLOUSTON, T. W. (1939) 'The Genetics of Black Arm Resistance. I'. *J. Genet.* xxxvii, pp. 133–59.

—— —— (1941) 'The Genetics of Black Arm Resistance. II and III'. *J. Genet.* xli, pp. 391–409.

—— (1944) 'The Genetics of Black Arm Resistance. IV. *Gossypium punctatum* Crosses'. *J. Genet.* xlvi, pp. 1–27.

—— 'The Theory and Application of the Backcross Technique in Cotton Breeding'. *J. Genet.* xlvii, pp. 76–86.

—— (in press) 'The Genetics of Black Arm Resistance. V. Dwarf-bunched and its Relationship to B_1'. *J. Genet.*

E. PLANT INTRODUCTION

Reports

1. Annual Reports[1] of the Botanical Section, Shambat, from 1920 to 1926. (Typewritten only.)
2. Annual Reports[1] of the Plant Introduction Section from 1936–7 to 1939–40 are included in Annual Reports of the whole research organization. (Those of 1936–7 and 1937–8 printed, others not yet duplicated.)
3. MYERS, J. G. *Provisional Report of the Economic Botanist on Yei–Maridi–Yambio Districts.* 1938. (Typewritten only.)

[1] Including work, described in Chapter XX, by R. E. Massey, T. Cartwright, J. G. Myers, and H. Ferguson.

F. PLANT PHYSIOLOGY

(*a*) *Annual Reports*[1]

1. Botanical Section, Shambat, from 1920 to 1925. (Typewritten only.)
2. Section of Plant Physiology and Pathology, Shambat, 1925–6 to 1929–30. (All typewritten only, except for 1926–7 to 1928–9, included in Agricultural Research Work in the Sudan and 1927–8 and 1928–9 included as appendixes to *Annual Report of the Department of Agriculture and Forests* for 1928 and 1929 respectively.)
3. Botanical Section, Gezira Research Farm, from 1922–3 to 1929–30. (All typewritten only, except for 1926–7 to 1928–9 included in Agricultural Research Work in the Sudan.)
4. Plant Observation Section from 1930–1 to 1937–8. Included in combined report of research organization.
5. Plant Physiology Section from 1928–9 onwards. Included in Agricultural Research Work in the Sudan in 1928–9. (Those for 1929–30 and 1930–31 not printed.) In the combined report of research organization from 1931–2 onwards.

   (For both 4 and 5 the combined reports duplicated from 1931–2 to 1934–5 and printed from 1935–6 to 1937–8. Later years of 5 not yet duplicated.)

(*b*) *Other Publications*

DAVIE, W. A. (1911) 'Note on the Growth of Cotton in the Sudan'. *Ann. Rep. Dept. Agric. Forests*, printed in *Reps. on Fin. Admin. & Cond. of the Sudan.*

CROWTHER, E. M. (1925) 'Some Aspects of the Soil Problem in the Gezira and Analysis of the Influence of Rainfall on the Yield of Cotton at the Gezira Research Farm'. *Rep. Meeting Sudan Gezira, Dec. 1925, Well. Trop. Res. Lab.*, pp. 18–28.

MASSEY, R. E. (1927) 'Recent Studies in Plant Physiology and Pathology'. *Rep. Meeting Khartoum, Jan. 1927, Well. Trop. Res. Lab.*, pp. 15–23.

LAMBERT, A. R. (1928) 'Flower Efficiency for Boll Production; Some Observations during 1927–8 Season'. *Rep. Meeting G.R. Farm, Dec. 1928, Well. Trop. Res. Lab.*, pp. 7–17.

GREGORY, F. G. (1928) 'Physiological Aspects of the Cotton Plant in the Gezira'. *Rep. Meeting G.R. Farm, Dec. 1928, Well. Trop. Res. Lab.*, pp. 37–44.

—— CROWTHER, F., and LAMBERT, A. R. (1930) 'The Inter-relation of Factors in Determining the Growth of the Cotton Crop in the Sudan'. *Emp. Cott. Gr. Conf., Aug. 1930*, pp. 112–29.

—— —— —— (1932) 'The Inter-relation of Factors Controlling the Production of Cotton under Irrigation in the Sudan'. *J. Agric. Sc.*, xxii, pp. 617–38.

—— (1934) 'Some Outstanding Physiological Problems in the Culture

[1] Including work, described in Chapter XX, by R. E. Massey, A. R. Lambert, E. M. Crowther, F. G. Gregory, F. Crowther, G. B. Portsmouth, and H. W. B. Barlow.

of Cotton in the Sudan'. *Emp. Cott. Gr. Corp., Second Conf. on Cotton Gr. Problems, July 1934*, pp. 206–22.

CROWTHER, F. (1934) 'Studies in Growth Analysis of the Cotton Plant under Irrigation in the Sudan. I. The Effects of Different Combinations of Nitrogen Applications and Water-supply'. *Ann. Bot.* xlviii, pp. 877–913.

CROWTHER, E. M., and CROWTHER, F. (1935) 'Rainfall and Cotton Yields in the Sudan Gezira'. *Proc. Roy. Soc.* Ser. B, cxviii, pp. 343–70.

LAMBERT, A. R., and CROWTHER, F. (1935) 'Further Experiments on the Interrelation of Factors Controlling the Production of Cotton under Irrigation in the Sudan'. *Emp. J. Exp. Agric.* iii, pp. 276–94.

CROWTHER, E. M. (1936) 'Rainfall and Cotton Yields in the Sudan Gezira'. *Emp. Cott. Gr. Rev.* xiii, pp. 1–10.

PORTSMOUTH, G. B. (1937) 'Variations in the Leaves of Cotton Plants Grown under Irrigation in the Sudan Gezira'. *Ann. Bot.*, N.S. i, pp. 277–92.

—— (1937) 'The Interrelation of Factors Controlling the Production of Cotton under Irrigation in the Sudan with Especial Reference to Variety'. *Emp. J. Exp. Agric.* v, pp. 318–26.

CROWTHER, F. (1941) 'Form and Date of Nitrogenous Manuring of Cotton in the Sudan Gezira'. *Emp. J. Exp. Agric.* ix, pp. 125–36.

—— (1941) 'Studies in Growth Analysis of the Cotton Plant under Irrigation in the Sudan. II. Seasonal Variation in Development and Yield'. *Ann. Bot.*, N.S. v, pp. 509–33.

—— and COCHRAN, W. G. (1942) 'Rotation Experiments with Cotton in the Sudan Gezira'. *J. Agric. Sc.* xxxii, pp. 390–405.

—— (1943) 'Influence of Weeds on Cotton in the Sudan Gezira'. *Emp. J. Exp. Agric.* xi, pp. 1–14.

—— and BARLOW, H. W. B. (1943) 'Tap-root Damage of Cotton, ascribed to Termites, in the Sudan Gezira'. *Emp. J. Exp. Agric.* xi, pp. 99–112.

—— (1944) 'Studies in Growth Analysis of the Cotton Plant under Irrigation in the Sudan. III. A Comparison of Plant Development in the Sudan Gezira and in Egypt.' *Ann. Bot.*, N.S. viii, pp. 213–57.

G. SOIL RESEARCH

Until 1931 work on soils was carried out by the Chemical Section of the Wellcome Tropical Research Laboratories, with headquarters in the Gordon Memorial College, Khartoum. In 1931 the section was split, most soil work being undertaken by the Soil Research Section at the Gezira Research Farm, Wad Medani, where laboratory work had started in 1923–4. In 1935 the chemical work remaining in Khartoum became centred in the Chemical Analytical Section. Only publications of agricultural interest are noted below.

(*a*) *Reports*

BALFOUR, A. (1904) 'Cyanogenesis in *Sorghum vulgare*'. *First Rep. Well. Res. Lab.*, pp. 46–8.

BEAM, W. (1906) 'Report of the Chemical Laboratory'. *Second Rep. Well. Res. Lab.*, pp. 205–44.

—— (1908) 'Report of the Chemical Laboratory'. *Third Rep. Well. Res. Lab.*, pp. 385–440.

EDIE, E. S. (1908) 'Notes on the Chemistry of Sudan Gums'. *Third Rep. Well. Res. Lab.*, pp. 441–50.

BEAM, W. (1911) 'Report of the Chemical Section'. *Fourth Rep. Well. Trop. Res. Lab.*, vol. B, pp. 23–72.

EDIE, E. S. (1911) 'Experiments on Gum Production'. *Fourth Rep. Well. Trop. Res. Lab.*, vol. B, pp. 73–84.

THOMPSON, J. (1911) 'Preliminary Notes on the Chemistry of the Latex of *Calotropis procera*'. *Fourth Rep. Well. Trop. Res. Lab.*, vol. B, pp. 85–94

(*b*) *Annual Reports*[1]

1. *Gordon Memorial College*, from 1905 to 1934, included as summary reports.
2. *Government Chemist*, from 1920 to 1931, included in list of bulletins below.
3. Work of the *Chemical Section* in *Agricultural Research Work in the Sudan* for 1926–7, 1927–8, and 1928–9. (For 1929–30 and 1930–1 not printed.)
4. *Gezira Chemical Section* (later *Soil Research Section*) for 1931–2 onwards, included in Annual Report of the research organization. (Duplicated from 1931–2 to 1934–5. Printed from 1935–6 to 1937–8. Later years not yet duplicated.)

(*c*) *Other Publications*

Pub. No.

1. BEAM, W. (1911) 'The Mechanical Analysis of Arid Soils'. *Cairo Sc. J.*, p. 107.

2. —— (1912) 'The Determination of Humus, especially in Heavy Clay Soils'. *Cairo Sc. J.*, p. 93.

3. —— (1913) 'The Determination of Humus in Heavy Clay Soils'. *Cairo Sc. J.*, p. 219.

4. —— and FREAK, G. A. (1914) 'Improvement in the Electrical Method of Determining Salt in Soils'. *Cairo Sc. J.*, p. 130.

7. —— (1914) 'Papyrus and Paper Manufacture'. *Cairo Sc. J.*, p. 283.

12. JOSEPH, A. F., and MARTIN, F. J. (1920) 'A Preliminary Account of the Chemistry of the Nile Sudd'. *J. Soc. Chem. Ind.* xxxix, pp. 91T–94T.

16. MARTIN, F. J. (1920) 'Properties affecting Strength in Wheaten Flour'. *J. Soc. Chem. Ind.* xxxix, pp. 246T–251T.

17. —— (1920) 'The Distribution of Enzymes and Proteins in the Endosperm of the Wheat Berry'. *J. Soc. Chem. Ind.* xxxix, pp. 327T–328T.

[1] Including work, described in Chapter XX, by W. Beam, A. F. Joseph, B. W. Whitfeild, H. Greene, O. W. Snow, H. B. Oakley, R. H. K. Peto, A. J. Henry, and T. N. Jewitt.

18. MARTIN, F. J. (1921) 'Report of the Government Chemist for the Year 1920'. *Well. Trop. Res. Lab., Chem. Sect.*
19. —— and MASSEY, R. E. (1921) 'Experiments on Wheat Growing in the Sudan'. *Well. Trop. Res. Lab., Chem. Sect.*
20. JOSEPH, A. F., and MARTIN, F. J. (1921) 'The Determination of Clay in Heavy Soils'. *J. Agric. Sc.* xi, pp. 293–303.
21. —— and WHITFEILD, B. W. (1921) 'The Briquetting of Charcoal'. *J. Soc. Chem. Ind.* xl, pp. 190T–192T.
22. —— (1922) 'Report of the Government Chemist for the Year 1921'. *Well. Trop. Res. Lab., Chem. Sect.*
23. JOSEPH, A. F., and WHITFEILD, B. W. (1922) 'Sudan Essential Oils'. *J. Soc. Chem. Ind.* xli, pp. 144T–145T and 172T.
24. —— and MARTIN, F. J. (1922) 'The Composition of Cows' Milk in the Sudan'. *The Analyst*, xlvii, pp. 426–9.
25. —— —— (1923) 'The Moisture Equivalent of Heavy Soils'. *J. Agric. Sc.* xiii, pp. 49–59.
26. —— (1923) 'Report of the Government Chemist for the Year 1922'. *Well. Trop. Res. Lab., Chem. Sect.*
27. JOSEPH, A. F., and MARTIN, F. J. (1923) 'The Hydrogen-Ion Concentration of Heavy Alkaline Soils'. *J. Agric. Sc.* xiii, pp. 321–32.
28. —— and HANCOCK, J. S. (1923) 'The Action of Silica on Electrolytes'. *Trans. Chem. Soc.* cxxiii, pp. 2022–5.
29. MARTIN, F. J., and MASSEY, R. E. (1923) 'Nitrification in Sudan Soils'. *Well. Trop. Res. Lab., Chem. Sect.*
30. —— (1924) 'Report of the Government Chemist for the Year 1923'. *Well. Trop. Res. Lab., Chem. Sect.*
31. JOSEPH, A. J., MARTIN, F. J., and HANCOCK, J. S. (1924) 'The Electrical Method for Determining Soil Alkali'. *Cairo Sc. J.* xii, pp. 141–3.
32. —— —— (1924) 'The Freezing Point of Sudan Milk'. *The Analyst Details*, pp. 420–3.
33. —— and HANCOCK, J. S. (1924) 'The Composition and Properties of Clay'. *Trans. Chem. Soc.* cxxv, pp. 1888–95.
34. —— (1924) 'The Composition of Some Sudan Soils'. *J. Agric. Sc.* xiv, pp. 490–7.
35. —— (1925) 'Report of the Government Chemist for the Year 1924'. *Well. Trop. Res. Lab., Chem. Sect.*
36. JOSEPH, A. F. (1925) 'Clay as Soil Colloids'. *Soil Sc.* xx, pp. 89–94.
37. —— (1925) 'Alkali Investigations in the Sudan'. *J. Agric. Sc.* xv, pp. 407–19.
38. —— and OAKLEY, H. B. (1925) 'The Action of Silica on Electrolytes. Part II'. *J. Chem. Soc.* cxxvii, pp. 2813–18.
38*a*. —— (1926) 'Report of a Meeting in the Sudan Gezira on Cotton Growing, December 1925'. *Well. Trop. Res. Lab., Chem. Sect.*, p. 35.
39. —— (1926) 'Report of the Government Chemist for the Year 1925'. *Well. Trop. Res. Lab., Chem. Sect.*

40. JOSEPH, A. F. (1926) 'Examination of the Soils of the Sudan'. *Fourth Int. Soil Sc. Conf. IVth Committee.*
41. —— (1926) 'Recent Studies in Heavy Alkaline Soils'. *Fourth Int. Soil Sci. Conf.*
42. OAKLEY, H. B. (1926) 'The Origin of the Charge on Colloidal Particles'. *J. Phys. Chem.* xxx, pp. 902–16.
43. —— (1927) 'Report of the Government Chemist for the Year 1926'. *Well. Trop. Res. Lab., Chem. Sect.*
44. JOSEPH, A. F., and WHITFEILD, B. W. (1927) 'The Organic Matter in Heavy Alkaline Soils'. *J. Agric. Sc.* xvii, pp. 1–11.
45. —— (1927) 'The Moisture Equivalent of Heavy Soils'. *J. Agric. Sc.* xvii, pp. 12–20.
47. —— (1927) 'The Determination of Soil Colloids'. *Soil Sc.* xxiv, pp. 271–4.
48. OAKLEY, H. B. (1927) 'The Action of Alkalis on Clay'. *J. Chem. Soc.*, pp. 2819–31.
49. —— (1927) 'Papers Read and Discussed at a Meeting of Research Workers held at Gordon College, Khartoum, on 14th January, 1927'.
50. —— (1928) 'Report of the Government Chemist for the Year 1927'. *Well. Trop. Res. Lab., Chem. Sect.*
51. OAKLEY, H. B. (1927) 'The Influence of Alkalis on the Coagulation of Silica and Clay Suspensions by Alkali Chlorides'. *J. Chem. Soc.*, pp. 3054–65.
52. JOSEPH, A. F. (1927–28) 'The Characterization of Clay'. *Trans. Ceram. Soc.* xxvii, pp. 1–11.
53. GREENE, H. (1928) 'A Soil Boring Apparatus'. *J. Agric. Sc.* xviii, p. 515.
54. —— (1928) 'Soil Permeability in the Eastern Gezira'. *J. Agric. Sc.* xviii, pp. 531–43.
55. —— (1928) 'Soil Profile in the Eastern Gezira'. *J. Agric. Sc.* xviii, pp. 518–30.
56. JOSEPH, A. F. (1927) 'The Laboratory Examination of Alkaline Soils'. *Trans. First Int. Cong. Soil. Sc.* iv, pp. 490–3.
56*a*. 'Report of Meeting of Research Workers held at the Gezira Research Farm, Wad Medani, December, 1928'.
57. JOSEPH, A. F., and SNOW, O. W. (1929) 'The Dispersion and Mechanical Analysis of Heavy Alkaline Soils'. *J. Agric. Sc.* xix, pp. 106–20.
58. —— and OAKLEY, H. B. (1929) 'The Properties of Heavy Alkaline Soils containing Different Exchangeable Bases'. *J. Agric. Sc.* xix, pp. 121–31.
59. —— (1929) 'Report of the Government Chemist for the Year 1928'. *Well. Trop. Res. Lab., Chem. Sect.*
60. PETO, R. H. K., and GREENE, H. (1929) 'Water Loss at Wad Medani. Part I'. *J. Agric. Sc.* xix, pp. 715–26.
61. —— (1930) 'Report of the Government Chemist for the Year 1929'. *Well. Trop. Res. Lab., Chem. Sect.*
63. —— (1931) 'Report of the Government Chemist for the Year 1930'. *Well. Trop. Res. Lab., Chem. Sect.*

63a. Greene, H. (1930) 'A Modification of the Barium Hydroxide Method for determining Exchangeable Hydrogen'. *Trans. Second Int. Cong. Soil Sc.*, pp. 25–7.

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[1]65a. 'Report of the Gezira Chemical Section for 1931–32'. *Gezira Agric. Res. Serv.*

[1]66a. 'Report of the Gezira Chemical Section for 1932–33'. *Gezira Agric. Res. Serv.*

[1]67a. 'Report of the Gezira Chemical Section for 1933–34'. *Gezira Agric. Res. Serv.*

69. Whitfeild, B. W., and Henry, A. J. (1935) 'Soil Nitrogen'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 224–6.

70. —— (1935) 'Soil Profile in relation to Yield'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 253–5.

71. Greene, H., and Snow, O. W. (1935) 'The Moisture Content of Irrigated Cotton Plots'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 1–4.

72. —— —— (1935) 'The Effect of Irrigation and Dry Fallow on a Heavy, Base-saturated Soil'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 21–4.

73. —— (1935) 'Soil Water Ratios in Base Exchange'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 63–5.

74. —— (1935) 'Soil Nitrates in the Sudan'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 217–19.

75. —— (1935) 'Soil Problems in the Sudan'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 350–3.

76. Snow, O. W., and Greene, H. (1935) 'The Nitrate Profile in an Arid Soil'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 354–63.

76a. Greene, H. (1936) 'Water Duty Trials in the Sudan Gezira'. *Trans. Third Int. Cong. Soil Sc.* iii, pp. 168–71.

77. —— (1934) 'The Effect of Irrigation on Soil Salts at the Gezira Research Farm, Wad Medani, Sudan'. *J. Agric. Sc.* xxiv, pp. 42–58.

[1]77a. 'Report of the Soil Research Section for 1934–35'. *Agric. Res. Serv.*

78a. Greene, H. (1937) 'Soil Problems of the Anglo-Egyptian Sudan'. *Emp. J. Exp. Agric.* v, pp. 1–10.

78b. 'Report of the Soil Research Section for 1935–36'. *Agric. Res. Serv.*

79a. 'Report of the Soil Research Section for 1936–37'. *Agric. Res. Serv.*

81. Greene, H. (1938) 'Colour Photographs of some Tropical Soils'. *Second Commission Int. Soc. Soil Sc.*, pp. 106–8.

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84. —— (1939) 'The Soils of the Anglo-Egyptian Sudan'. *Sonderabdruck aus bodenkundlichen Forschungen Bd.*, vi, pp. 325–38.

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40. JOSEPH, A. F. (1926) 'Examination of the Soils of the Sudan'. *Fourth Int. Soil Sc. Conf. IVth Committee.*
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55. —— (1928) 'Soil Profile in the Eastern Gezira'. *J. Agric. Sc.* xviii, pp. 518–30.
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[1]65. —— (1932) 'Report of the Government Chemist for the Year 1931'. *Well. Trop. Res. Lab., Chem. Sect.*
[1]65a. 'Report of the Gezira Chemical Section for 1931–32'. *Gezira Agric. Res. Serv.*
[1]66a. 'Report of the Gezira Chemical Section for 1932–33'. *Gezira Agric. Res. Serv.*
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69. WHITFEILD, B. W., and HENRY, A. J. (1935) 'Soil Nitrogen'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 224–6.
70. —— (1935) 'Soil Profile in relation to Yield'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 253–5.
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73. —— (1935) 'Soil Water Ratios in Base Exchange'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 63–5.
74. —— (1935) 'Soil Nitrates in the Sudan'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 217–19.
75. —— (1935) 'Soil Problems in the Sudan'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 350–3.
76. SNOW, O. W., and GREENE, H. (1935) 'The Nitrate Profile in an Arid Soil'. *Trans. Third Int. Cong. Soil Sc.* i, pp. 354–63.
76a. GREENE, H. (1936) 'Water Duty Trials in the Sudan Gezira'. *Trans. Third Int. Cong. Soil Sc.* iii, pp. 168–71.
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[1]77a. 'Report of the Soil Research Section for 1934–35'. *Agric. Res. Serv.*
78a. GREENE, H. (1937) 'Soil Problems of the Anglo-Egyptian Sudan'. *Emp. J. Exp. Agric.* v, pp. 1–10.
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[1] Duplicated only.

85. 'Report of the Soil Research Section for 1937–38'. *Agric. Res. Serv.*
86. JEWITT, T. N. (1940) 'Sorption by Clays'. *Soil Sc.* l, pp. 163–73.
87. SNOW, O. W. (1938) 'Physical Changes in the Soil of the Gezira'. *Emp. Cott. Gr. Corp., Rep. Third Conf.*, pp. 67–9.
88. JEWITT, T. N. (1941) 'Dispersion Studies on Gezira Soils'. *J. Agric. Sc.* xxxi, pp. 466–78.
89. —— (1942) 'Loss of Ammonia from Ammonium Sulphate applied to Alkaline Soils'. *Soil Sc.* liv, pp. 401–10.
90. GREENE, H., and JEWITT, T. N. (1944) 'Charcoal Briquettes as Locomotive Fuel'. *Nature*, cliv, p. 58.
91. GREENE, H. (1945) 'Report on Sub-soil Water Movement near Debeiba, 1940–43'. *Chem. Pub. No. 91, Khartoum.*
92. —— and JEWITT, T. N. (1945) 'Charcoal Briquettes as a Coal Substitute'. *J. Soc. Chem. Ind.* lxiv, pp. 265–71.
93. JEWITT, T. N. (in press) 'Nitrification in Sudan Gezira Soil'. *J. Agric. Sc.*

(*d*) *Other Miscellaneous Publications*

MARTIN, F. J., and GRAY, H. R. (1921) 'Methods of Accelerating the Germination of Seeds'. *Sudan Notes and Rec.* iv, pp. 165–8.

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GREENE, H., and BAILEY, M. A. (1935) 'Drainage in the Sudan Gezira'. *Emp. Cott. Gr. Rev.* xii, pp. 208–15 and 360.

KENCHINGTON, F. E. (1935) 'Relationships of Roots, Soil Profile and Irrigation in the Sudan'. *Journ. S.E. Agric. Coll. Wye*, No. 36, pp. 135–81.

TOTHILL, J. D. (1946) 'The Origin of the Sudan Gezira Clay Plain'. *Sudan Notes and Records*, vol. xxvii.

GLOSSARY OF ARABIC AND VERNACULAR WORDS

Compiled by J. D. TOTHILL

MANY of these words are Arabic or of Arabic origin, and I am indebted to Dr. Nowaihi, Reader in Arabic at the Gordon Memorial College, for correcting spellings and for suggesting literal meanings.

There is a residue of words associated with irrigation and with clay lands rather than with desert; most of these were probably in use before the Arab invasion of Africa, and they probably derive from ancient Egypt and from southern languages. I hope that some day someone will sort out these words and explain from what sources they have come because such information would add to our knowledge of the beginnings of agriculture in the Sudan.

Where spellings in the text differ from those in this glossary the latter are to be preferred.[1]

abri, a thirst-quenching, non-alcoholic drink produced by soaking dried 'kisra' or dura pancake flakes in water.

abu sitta and *abu 'ishrīn*, watering-channels in the Gezira. Lit. the father of six, and of twenty, piastres paid per unit of excavation.

'adār, several species of *Sorghum* grass indigenous in the Sudan. Specially *S. arundinaceum* Stapf.

adlīb, the maritime salt bushes, *Suaeda monoica* Forsk. and *S. fruticosa* Forsk.

'ads masri, Ar. for the Egyptian lentil, *Lens esculenta* Moench.

'ads sudāni, Ar. for Sudanese lentil or pigeon pea, *Cajanus cajan* (L.) Millsp.

'afin, Ar. for rotten or stinking, e.g. *lubia 'afin.*

ālas, strong rope made from the flower-stalks of the date-palm used for tying cattle.

ananas, Central American name for the pineapple, *Ananas sativa* Schult.

'andat, the dura bug, *Agonoscelis versicolor* F.

angaia, in the Gezira one of the sixteen parallel strips into which a 10-feddan holding is divided.

'angarīb, an indigenous type of bedstead laced with rope.

anīs, the 'harīq' grass *Sorghum purpureo-sericeum* Aschers and Schweinf.

ansora, the 'harīq' grass *Hyparrhenia pseudocymbaria* Stapf. Also called *umm ritsū.*

'aradēb or *'aradeib*, Ar. for the tamarind tree, *Tamarindus indica* Linn.

arāk, Ar. for the toothbrush tree, *Salvadora persica* Gareim.

'araqi, a potent spirit distilled from fermented date liquor.

arbaīn, Ar. for 40, and so the 40-day camel road from Kordofan Province to Assiut in Egypt.

'arbūn, col. Ar. for a cash advance.

[1] See also the explanation of treatment of Arabic words on p. 7.

ardeb, pl. *arādeb*, Ar., a measure of capacity for agricultural produce equalling 198 litres.

1 ardeb of dura weighs 336 rotls.
1 „ dukhn „ 360 „
1 „ simsim „ 264 „

Admitted to English with pl. ardebs.

arrāda, a small tree, *Albizzia sericocephala* Benth. Common in Nuba Mountains area.

'asal, Ar., literally honey, but also applied to aphids that exude a sticky substance.

'asalīya, Ar. for honeyed, and locally a drink made from *nabīt* with the addition of sprouted dura.

'ashub, see *'ushub*.

'asīda, col. Ar., a dough cooked into a porridge made from dura, dukhn, or wheat, and a very common article of food in the northern Sudan.

'assāra, an indigenous type of oil press operated by a camel or by oxen.

atawīl, the fodder plant, *Astragalus prolixus* Sieb.

babaia, the pawpaw, *Carica papaya* L.

babanūs, a small tree, *Dalbergia melanoxylon* G. and P., with black heart-wood. Ebony.

babūn, *Vigna vexillata* Benth.

bādōb, cracking clay soil.

bafra, the cassava plant, *Manihot utilissima* Pohl.

baghīl, the fodder plants *Blepharis linariifolia* Pers. and *B. persica* (Burmf.) Kuntze, both of which occur as weeds in the Gash area.

baladi, Ar. relative adj. from *balad*, a village, often used to describe the common local variety of a crop.

balagh, areas in the Gash Delta used for silt deposition prior to use of water for irrigation. Land flooded by natural overflow.

balah, the fruit of the date-palm, *Phoenix dactylifera* L.

balilla, seeds of 'lubia 'afin', *Dolichos lablab* Linn., boiled green.

bambei, the sweet potato, *Ipomoea batatas* (L.) Lam. A corruption from Bombay.

bamia, col. Ar. for lady's fingers or okra, *Hibiscus esculentus* Linn.

ban, Ar. for the willow-tree, *Salix aegyptiaca* Forsk., a favourite food of young camels.

banadora, col. Ar., the tomato, *Lycopersicum esculentum* Mill.

barāmka, a social society in the Nuba Mountains that has developed into a society for conducting agricultural operations known as the 'nafir' system. (From Barmacides?)

bashām, Ar., the fibre-producing *Grewia mollis* Juss.

bashendi, a type of non-alluvial clay soil in the Gedaref area remote from hills but with quartz stones on the surface and esteemed for cultivation.

basilla, col. Ar., the pea, *Pisum sativum* L.

basl, Ar., the onion, *Allium cepa* L.

bastūrma, col. Ar., meat cut into thick slabs, sun dried, and salted, and intended for early consumption.

batha, household vessel used for storing such items as clarified butter.

battīkh, Ar., the water-melon, *Citrullus vulgaris* Schrad.

bedingān, Ar. from the Persian, the egg-plant, *Solanum melongena* L.

bersīm el hegāz, Ar., lucerne or alfalfa, *Medicago sativa* Linn.

bersīm masri, Egyptian clover, *Trifolium alexandrinum* Linn. Rarely planted in the Sudan.

bighēl, *Blepharis linariifolia* Pers.

bilād, Ar. pl. of *balad*, village periphery lands on which cultivation is perennial, without resting periods.

binnū, the pretty grass *Eragrostis tremula* Hochst. Eaten by camels.

birāza, a rake consisting of a forked branch from a tree with prongs about 6 in. long.

bōr, Ar. meaning uncultivated or barren land. In the Gezira means resting land, generally in a rotation.

bortuqān, the sweet orange: a corruption of Portugal, as the Portuguese introduced this fruit from China.

buda, the parasitic weed *Striga hermonthica* Benth. that attacks dura.

bugr, land in Khartoum Province lying behind the 'sāqiya' land and cultivated only rarely when rains have been good or the flood exceptionally high.

bulo or *telebun*, the grain eleusine, *Eleusine coracana* Gaertn.

bunn, Ar. for coffee powder, locally means coffee, either *C. arabica* L. or *C. canephora* Pierre.

burām, Ar. pl. of *burma*, fired earthenware jars.

burdi, Ar. for papyrus; locally the bulrush of the Sudd area *Typha australis* Schum. and Thonn.

burma, an earthenware jar.

bursh, col. Ar., matting used for making containers for marketing agricultural produce.

butig, a ratoon crop.

dahassīr, the woody scarlet-flowered *Indigofera oblongifolia* Forsk.

dahrat, plains on both sides of the Blue Nile river in the Blue Nile Province largely composed of cracking clay.

dakkai or *kabad*, a strong wine made from dried dates.

dameira, col. Ar., the season of the year when the Nile is in flood. Perhaps from 'damar', to destroy.

danab el ʿaqrab, Ar., lit. tail of the scorpion. The herb *Heliotropium europaeum* Linn.

danab el kalb, Ar., lit. dog's tail.

(*a*) *Celosia argentea* Linn., a common weed of cultivation.

(*b*) *Setaria phacelata* Stapf *and* Hubbard.

danabāya, col. Ar. for little tail. The grass *Aristida steudeliana* Trin. and Rupr.

dandy or *tandi*, the Darfur name for homespun cotton.

debba, col. Ar., sand-dunes. In the Tokar Delta the dunes are mostly composed of silt and are for the most part active. Perhaps from 'dabba', to creep.

dergo, the fibre-producing plant *Chrozophora crocchiana* Vis. Also called *ergisi*.

derīs or *drīs*, hay made from lucerne, *Medicago sativa* Linn.; 'daras' means to thresh corn.

dhangeil, the wheat rust *Puccinia graminis* Per.

diel, a clan owner of the Nuer tribe.

difra, an excellent fodder grass, *Echinochloa colona* Link.

dikwa, balls of crushed sesame as used by Fallata people.

dimin, a large holding of land, particularly in the Tokar Delta. Perhaps from Ar. *diman*, a dunghill.

dirim or *dirmi*, one of the 'gizu' fodder plants, *Indigofera arenaria* A. Rich.

dīs, *Cyperus* sp., mainly *C. rotundus* L.; same as 'sēd' or 'seid'. A sedge and a thoroughly bad weed.

dolēb, the large fan palm, *Borassus aethiopium* Mart.

dōm, the common branching palm, *Hyphaene thebaica* Mort.

drīs, see *derīs*.

dukhn, col. Ar., the food grain *Pennisetum typhoideum* (Burm.) Stapf and Hubbard, the main grain crop in sandy areas.

dukhn misikhat, the 'harīq' grass, *Pennisetum mollissimum* Hochst.

duma, a fermented drink made from honey.

dumbalab, the grass *Aristida mutabilis* Trin. and Rupr.

dura, the great millet, *Sorghum vulgare* Pers. From Ar. *udhra*, millet.

dura shami, col. Ar. for maize; lit. Syrian millet.

dyil, hereditary owner, for ritual purposes, of land among the Shilluk tribe.

'ein es shems, Ar., lit. the sun's eye, locally the sunflower, *Helianthus annuus* Linn.

el kog, the ubiquitous tropical grass, *Eleusine indica* Gaertn.

el milēha, the fodder grass *Schmidtia pappophoroides* Steud.

'enab, Ar., the grape vine, *Vitis vinifera* L.

ergisi, the fibre-producing plant, *Chrozophora crocchiana* Vis. Also called 'dergo'.

farwa, see *furwa*.

fas, Ar., a primitive type of axe with a soft iron wedge-shaped blade about 2 lb. in weight.

fasil, Ar. for dividing-line, the boundary line of a block of 'gerf' land running at right angles to the river. The boundary running parallel with the river is called a 'mirin'.

fasulia, the haricot bean, *Phaseolus vulgaris* Linn.

fasulia 'arīda, lit. broad bean, the lima bean, *Phaseolus lunatus* L.

feddan, an area of land approximately equal to an acre.

1 *feddan* = 1·038 acres = 0·420 hectares.

Admitted to English with pl. feddans.

ferīq, Ar. for group, locally a herd of camels or of cattle.

figl, Ar., the radish, *Raphanus sativus* L.

fūl or *fūl sudāni*, Ar. for beans, the ground-nut, *Arachis hypogaea* L.

fūl abu ngawi, the bambara ground-nut, *Voandzeia subterranea* Thou.

fūl masri, Ar., the tick bean, *Vicia faba* Linn.

fula, a large pool.
fundūq, a wooden mortar used for pounding foodstuffs.
furwa or *farwa*, Ar. 'fur', saddle-cloth made from a sheepskin tanned with the hair or wool intact.

gaddēm, a small shrub, *Grewia betulifolia* Juss.
gadwal, pl. *gadāwil*, a channel or very small canal used for irrigation.
gammēz, Ar., lit. sycamore-tree, locally the common wild fig-tree, *Ficus sycamorus* Linn.
gamsha, see *qamsha*.
gangoleis, the fruit of the 'tebeldi', *Adansonia digitata* Linn.
garāwi, Sudan grass, *Sorghum sudanense* Stapf; and Johnson grass *S. halepense* Pers.
gardūd, Ar. 'garad', to scrape. Soils formed near the base of hills by the weathering of rocks. Used particularly in Kordofan Province.
gargīr, col. Ar., the rocket cress, *Eruca sativa* Mill.
gassab, see *qassab*.
gassab sukkar, see *qassab sukkar*.
gau, the grass *Andropogon gayanus* Kunth., also used for *Aristida funiculata* Trin. and Rupr.
gaw, a seedling date-palm, and normally of poor quality.
gawāfa, the guava-tree, *Psidium guajava* L.
gehād, Ar. for strife or struggle, hence sometimes it means an uprising.
gerf, Ar., the sloping land of a river-bank or small pockets of silt land cultivated by 'selūka' as the waters subside after the annual flood.
ghabash, col. Ar., the dry-standing tussocks of fodder grasses of the genus *Aristida*.
gibba, Ar., a loose-fitting shirt-like outer garment.
gilban, the chickling vetch, *Lathyrus sativus* Linn.
gitta, see *qit'a*.
gizu, Ar. *gaz*, to subsist on juicy plant without water, and applied to a waterless area in the northern Sudan where camels are put out to winter-grazing and in which the peculiar vegetation supplies the only moisture.
gizya, Ar., a poll-tax on male non-Moslem subjects.
gogēb, the forage plant *Heleochloa schoenoides* Host.
gregdan, the fibre-producing shrub *Dombeya multiflora* Pl.
gugu, a cylindrical bin about 4 ft. in diameter set on wooden posts about 3 ft. above the ground used in Equatoria Province for storing grain.
gurtum, see *qurtum*.
gussābia, see *qassābia*.

hababai, the winter trade winds, particularly of the Tokar Delta area. They are easterly to north-easterly and persist until the onset of the winter rains.
habūb, Ar., to blow violently, locally a strong wind, not the trade wind, usually accompanied by thick dust.
habwa, the Cape gooseberry, *Physalis peruviana* L.
hadd, the herb *Cornulaca monocantha* Del.
hafīr, pl. *hafirāt*, Ar., a pit, locally a pool usually made by man.

halfa, Ar. *halfā*, bulrushes, the coarse tufted desert grass *Demostachya cynosuroides* Stapf, used as a source of fibre.
hamla, Ar. 'hamal', to carry, locally a train of pack animals.
hamra, a fodder grass in the genus *Aristida*.
handagōg, a *Trigonella* useful for forage.
handal, from Ar. 'hanzal', the colocynth, the cucurbit *Citrullus colocynthis* L. with a bitter pulp containing colocynthin.
hantūd, the herb *Ipomoea cardiosepala* Hochst., a common weed but useful as a fodder plant.
harāz, the large forest tree *Acacia albida* Del.
harīq, Ar. for conflagration, applied locally to a type of cultivation based on firing the old stand of grasses just prior to sowing.
hashāb, the shrubby tree *Acacia senegal* Willd., the source of the best kind of commercial gum.
hashhāsha, from Ar. 'hashīsh' meaning grass or weeds, locally a weeding-hoe of the pushing type: same as 'malōd'.
hashīsh, Ar., the Indian hemp, *Cannabis sativa* L. Forbidden by law, but grown surreptitiously.
haskanīt or *heskanīt*, an important forage grass with extremely unpleasant spiny fruits, *Cenchrus biflorus* Roxb. False 'haskanīt' is the related *Cenchrus ciliaris* Linn.
hawāya, col. Ar., a pack-saddle.
haza or *mehleb*, the aromatic herb *Ruta tuberculosa* Forsk., used as a corrective against sterility in dates and women.
heglīg, a ubiquitous tree with straight green spines and edible fruit, *Balanites aegyptiaca* Del.
hekabīt, the caper bush, *Capparis tomentosa* Lam.
helba, col. Ar., fenugreek, *Trigonella foenum-graecum* L. Grown for its seeds.
hemēra, the grass *Eragrostis aspera* Nees. Eaten by camels: fairly good.
hemeyr, the small grey beetle, *Tanymecus sparsus* Fhs., that nips off dura cotyledons.
hemra or *hamra*, the grass *Aristida adscensionis* Linn.
henna, Ar., the henna of commerce, *Lawsonia alba* Lam.
hōd, Ar. for basin or trough.

(*a*) A compartment of irrigated land.
(*b*) In the Tokar Delta a 'hōd' is a basin or unit of 15 to 65 'murabba', each of which is a square of 160 feddans.
(*c*) In the Gash Delta a 'hōd' is a large area of 4,000 feddans.

homēd, Ar. meaning acid, a small to fairly large tree, *Sclerocarya birrea* Hochst., with purple inflorescence and yellow edible fruit.
homra, the grass *Eleusine flagellifera* Nees. Eaten by camels.
howāsha pl. *āt*, col. Ar. from word meaning to hold, a holding of land; in the Gezira means a tenancy of 10 feddans.
hummus, Ar., the chick-pea, *Cicer arietinum* Linn., grown on the wettest part of basin lands in Northern Province.

inderāb intaya, *Cordia abyssinica* R. Br. Small tree, excellent camel fodder.

kabad, a strong wine made from dried dates.

kadada, the conspicuous spiny shrub, *Dichrostachys glomerata* Choiv., with thimble-shaped heads of pink and yellow flowers.

kakamūt, the bush or small tree *Acacia campylacantha* Hochst.

kalatōd, a pair of water-wheels situated one above the other for lifting water a great height. The trickle of water lifted, for work done, is very small.

kalleiga, a bundle sometimes applied to a type of dura; also applied to bundles of dura straw or 'qassab', offered for sale, weighing 4 to 10 rotls.

kankar or *kunkar*, white to greyish calcium carbonate nodules in soils that near the river may take the form of branching root-like cylinders.

kantar, a unit of weight; normally 1 kantar = 100 rotls = 99·05 lb. In the Gezira 1 kantar of cotton means 315 rotls or 312·01 lb. of unginned cotton. Admitted to English with pl. kantars.

karāwia, col. Ar., the caraway, *Carum carvi* L.

karbōl, a type of sowing-stick used in the White Nile area.

karū, land in Shendi district lying behind the 'sāqiya' land, cultivable only when the Nile is exceptionally high or when the accident of a good rain has occurred.

kās, Ar. a gourd container for water.

kasbara, the coriander, *Coriandrum sativum* L.

kashrengeig, trade name of *Dolichos lablab* L. beans exported to Egypt.

kēla, a unit of capacity; normally 12 kēla = 1 ardeb, but there are exceptions.

kēla or *keila*, Ar., a measure of capacity equal to 16·5 litres.

kerkade, the roselle hemp, *Hibiscus sabdariffa* L.

kerrib, land consisting of eroded water channels cutting from plain to valley along the Atbara and Blue Nile rivers.

khabīr, Ar., lit. expert, a camel transport sub-contractor.

khalwa, Ar., lit. private room, a Koranic school where religious precepts and literacy are traditionally taught by rote learning.

kharāg, Ar., a revenue tax on land in accordance with area or produce.

kharīf, Ar. for autumn, locally the rainy season.

kharroub, col. Ar., the fibre-producing shrub or small tree *Bauhinia reticulata* DC.

khashkhāsh, Ar. for poppy, *Stereospermum kunthianum* Cham., a small tree with lovely flowers.

khirwa, Ar., the castor plant, *Ricinus communis* Linn.

khiyār, col. Ar., the cucumber, *Cucumis sativus* Linn.

khums, Ar., dues amounting to one-fifth of crop value paid to the ruling family in Singa district.

khutt, col. Ar., a tribal division.

kifāyat yed, Ar., enough for the hand, locally an area of land in a Kordofan village allotted to an individual for working by hand.

kimūn akhdar, Ar., cumin, *Cuminum cyminum* L.

kina, col. Ar. from quinine, the quinine-tree: applied generally to all species of *Cinchona*.

kindi, the Bongo name for *Hyptis spicigera* Lam., used as food in Equatoria Province.

kino, same as 'kindi'.

kisra, col. Ar., lit. morsel, flat cakes of unleavened bread usually made of dura flour and the foundation of the diet in central and northern Sudan.

kiteih or *keteih*, *Trigonella laciniata* Linn., a useful fodder crop in the basins of Northern Province.

kitr, a common shrub or small tree with particularly vicious thorns and highly scented blossoms, *Acacia mellifera* Benth.

kittān, Ar., flax, *Linum sativum* L.

kommadōb, land in the Gedaref area free from weeds due to 'harīq' burning in the previous season.

koreib or *korēb*, an indigenous grass, *Dactylotenium aegyptium* Beauv., the seeds of which are used for food in Darfur Province. Also a good forage plant.

korēk, col. Ar., a shovel.

kowal, a sauce for use with ''asīda' prepared by the Jebel Marra people from *Cleome viscosa* Linn.

kugur, a witch-doctor in the Nuba Mountains.

kūk, a large tree, *Acacia sieberiana* DC., prominent along rivers south of the latitude of Renk.

kulkul, *Bauhinia rufescens* Lam., excellent fodder for camels; also the source of a fibre.

kullega, bundles of dura straw or 'qassab'.

kurmut, the round-leaved shrub *Cadaba rotundifolia* Forsk.

kurmut sighaiyr, the bush *Cadaba glandulosa* Forsk., good camel fodder; slightly purgative.

kutla, Ar., a stick of timber for taxation purposes measuring 42 in. in mid-girth.

lablab ahmar, lit. red lablab, the amaranth, *Digera arvensis* Forsk.

lalob, the fruit of the 'heglīg' or *Balanites aegyptiaca* Del.

la'ōt, an obconical shrub, *Acacia orfota* (Forsk.) Schweinf. In places very common.

lebbād, col. Ar., a stretch of fine alluvial silt land in the Gash Delta.

lebbak or *lebbek*, *Acacia lebbek* Benth.

lebūn, Ar., lit. milky, locally various species of *Euphorbia*.

libās, Ar., the baggy trousers or drawers of the Arab.

limūn beladi, Ar., the lime, *Citrus aurantiifolia* (Christm.) Swingle.

luak, the Dinka cattle byre: it is a large cone-shaped building of mud and wattle construction on a pole framework.

lubia or *lubia 'afin*, col. Ar., the bean *Dolichos lablab* Linn., grown for human food, but mostly for forage, in the northern Sudan and a most important crop.

lubia el fil, Ar. meaning elephant's bean, locally the sword-bean *Canavalia ensiformis* DC.

lubia hilu, col. Ar., lit. sweet bean, locally the cow-pea, *Vigna unguiculata* (L.) Walp.

lukh, the fodder grass, *Sporobolus helveolus* Durand and Schinz.

lulu, the shea-butter tree, *Butyrospermum parkii* var. *niloticum* Kotschy, a source of a valuable edible oil used extensively in Equatoria Province.

luqma, Ar. for morsel of bread, locally dura porridge.
luwēs, the bush *Leptadenia heterophylla* Decne.

mahagaya, the forest tree *Celtis integrifolia* Lam.
mahal, Ar. meaning unfertile, as distinct from 'harīq', is land on which weed growth is poor because of a seed failure due to poor rains in the previous year.
maharīb, the tussock grass *Cymbopogon proximus* Stapf.
maiya, basins left by the receding river, particularly in Blue Nile Province.
malōd, a pushing type of hoe.
manga, col. Ar., the mango-tree, *Mangifera indica* L.
marabba, see *murabba*.
marad ed dam, Ar., lit. blood disease, locally a disease of simsim caused by *Pseudomonas sesami* Malkoff.
marīsa, beer made from various grains, but chiefly dura, in the central and southern Sudan; a valuable protective food.
marōq, nitrogenous earth from the desert between the river and the hills in the northern Sudan.
masah or *masih*, the *Sorghum* midge, *Contarinia sorghicola* Coq.
mashandow, a sandy patch of land in the Gash Delta.
matara, col. Ar. from word meaning rain: a Persian water-wheel or 'sāqiya' working from a well.
matmūra, col. Ar. from word meaning to bury in the soil; pits for storing grain, particularly dura.
meglis, Ar., the council in the Gezira scheme to which the 'samad' is responsible.
meglis ahli, Ar., a local Sudanese council.
mehleb or *haza*, the aromatic weed *Ruta tuberculata*, Forsk., used as a corrective against sterility in dates and women.
mek, the chief or ruler of a small political unit in the Nuba Mountains.
melūkhīya, leaves and tender shoots of young plants of the jute plant, *Corchorus olitorius* Linn., used widely for making thick soup.
merakh or *marakh*, the switch-like desert bush *Leptadenia spartium* Wight.
meteig, leaf-pruning of wheat in Northern Province.
milgat, the herb *Ipomoea hederacea* Jacq., sometimes cultivated for its seeds which have medicinal properties.
millieme, a unit of money.

975 milliemes = 97·5 piastres = £1 sterling.
48·75 milliemes = 1 shilling.
4·0625 milliemes = 1 penny.
1,000 milliemes = £E1.000.

mirin, an imaginary boundary in the river used for demarcating 'gerf' land. This boundary lies parallel with the river. The boundary at right angles to this is called a 'fāsil'.
mirrara, from Ar. word meaning bile, locally bile used to flavour fresh viscera of slaughtered animals.
misqa, col. Ar. from word meaning to irrigate, locally a branch canal in the Gash irrigation scheme.

mohfār, col. Ar. from word meaning to dig a hole, locally a type of sowing-stick resembling the 'torea', but with the iron head long, narrow, and pointed.

mokhēt, a small tree, *Boscia senegalensis* (Pers.) Lam., with sweet-scented flowers and edible fruit.

molēta, the herb *Picridium tingitanum* Desf.

mordēb, the grass *Paspalidium desertorum* Stapf, which becomes a weed in the Gash.

mōz, col. Ar., the banana plant, *Musa sapientum* L.

mulah, a meat and vegetable stew.

mungal, Ar., the sickle: a very ancient type of harvesting tool consisting of a short saw-edged iron blade fitted to a short wooden handle.

murabba, Ar. for a square; in the Tokar Delta a division of land of 160 feddans measuring 800 × 840 metres; in the Gash Delta the sides of a 'murabba' measure 820 metres.

murhaka, col. Ar., a stone used for grinding wheat or dukhn.

na'al, the thatching grass, *Cymbopogon nervatus* Chiov.

nabaq or *sidr*, Ar., the thorny and ubiquitous bush *Ziziphus spinachristi* Willd. with edible fruit.

nabīt, from Ar. 'nabīdh', a drink made from dry dates boiled in water and stored in jars.

nafir, Ar., a system of co-operative agriculture in the Nuba Mountains district in which the men of one or more villages bind themselves into a 'baramka' for agricultural purposes.

nagīl, col. Ar., the grass *Cynodon dactylon* Pers.

nahla, col. Ar., 'dōm' palm splits used for building.

nakhla, Ar., the date-palm, *Phoenix dactylifera* L.

nāl or *na'al*, the 'harīq' grass, *Cymbopogon nervatus* Chiov.

nārang, the Arabic word from which derives the word orange.

nigam, a short-handled weeding-hoe.

nila, col. Ar., Indigo plants of the genus *Indigophora*.

nissa, the 'gizu' grass, *Aristida ciliata* Desf.

nōrag, col. Ar., an animal-drawn wheat-threshing machine with disk-like wheels fixed in a frame.

ombāz, oilcake made from sesame, *Sesamum orientale* Linn.

piastre or *piastre tarifa*, P.T. for short, a unit of money. 100 P.T. = £E1.000. 97·5 P.T. = £1 sterling.

qābura, the hairy-chested locust, *Locusta migratoria migratorioides* Rch. and Frm.

qabūra, small grasshoppers, as distinct from 'qābura', the hairy-chested locust.

qadah, wooden bowls: when slung in plaited rope cradles may be objects of considerable beauty.

qādūs, pl. *qawādīs*, col. Ar., water-pots of a 'sāqiya' wheel.

qafal, the tree *Commiphora africana* Engl. Leaves eaten by camels and cattle.

qammēz, see *gammēz*.

qamsha, the tobacco plant, *Nicotiana tabacum* L., and its product.

qarad, col. Ar., the pods of the sunt-tree, *Acacia arabica* Linn., used for tanning.

qassab, Ar. for cane, the straw of dura, maize, or dukhn, and a very important animal food in the northern Sudan.

qassab sukkar, Ar., sugar-cane, *Saccharum officinarum* Linn.

qassābia, an earth scoop of wood or iron, drawn by oxen. Used for making or levelling canal banks.

qirba, pl. *qirab*, Ar., a water-carrier made from the skin of an animal, usually sheep.

qishta, Ar. for cream, locally the custard apple, *Anona squamosa* L.

qism, Ar., lit. portion or part, locally an area of land about the size of a political district.

qitʿa, Ar. for portion, a unit of land in the Gash Delta of 10 feddans.

qōz, col. Ar., sand-dune; 'qōz' country means any part of that vast area of billowy continental sand occurring in Darfur and Kordofan and Northern Provinces.

qulqās, col. Ar., the coco-yam, *Calocasia antiquorum* Schott.

qurer, silt land along the river-bank just above high Nile flood-level. Watered by 'sāqiya' or by 'shadūf'.

qurtum, Ar., the safflower, *Carthamus tinctorius* L.

qutn, Ar., cotton.

rassās, col. Ar., a stick of timber for taxation purposes measuring 15 in. in mid-girth.

reika, a large strong receptacle of plaited fibre used in houses by the Fur people.

rigla, col. Ar., purslane, *Portulaca oleracea*, L.

rihān, Ar., the camphor herb, *Ocimum kilimandscharicum* Gurke, and other species of the same genus.

rōb, col. Ar., soured milk used by nomads.

romān, Ar., the pomegranate, *Punica granatum* L.

rotl, Ar., a measure of weight approximately one pound.

112 lb. = 113 rotls.
100 rotls = 99·05 lb. = 44·94 kg.
Admitted to English with pl. rotls.

ruzz, col. Ar., a species of wild rice growing in marshy land: excellent fodder plant for cattle. *Oryza barthii* Chev.

ruzz el wādi, col. Ar., the wild rice, *Oryza punctata* Kotschy, of the sudd marginal area.

saʿadān, Ar., the herb *Neurada procumbens* Linn. One of the 'gizu' plants.

saʿat, *Premna resinosa* Schauer, eaten greedily by camels.

sabarok, leaves of 'bamia', *Hibiscus esculentus* Linn., prepared for human food.

s'ad, a *Cyperus* species used for grazing in the Upper Nile Province.

sadd, pl. *sudūd*, Ar. for barrier and hence the 'sudd' area of swamp lands.

safeira, the herb *Dipterygium glaucum* Dec.

safsāf, Ar., the willows *Salix muriellii* Skan. and *S. subserrata* Willd., both occurring on the banks of the Blue Nile.

sahab, the graceful tree *Anogeissus shimperi* Hochst., with fruit resembling small brown cones.

salāla, the common square-stemmed climbing plant *Cissus quodrangulatus* Linn., belonging to the grape family.

salam, Ar., the desert scrubby tree *Acacia flava* (Forsk.) Schweinf. Good camel fodder.

salība, from Ar. 'salīb', a cross, earthen cross-banks to control basin irrigation in the Northern Province.

sallam, see *salam*.

salsa, from Ar. word meaning sauce, locally sun-dried tomato, a minor export from Darfur Province.

samad, Ar., a local agricultural authority in the Gezira Scheme responsible to the village council.

sambūk or dhow, a sea-going deep-keel vessel fitted with lateen sails.

samn or *semn*, clarified butter with the water driven off by boiling.

samr, Ar., the flat-topped desert bush, *Acacia tortilis* (Forsk.) Christensen.

sāqiya, Ar. from word meaning to irrigate, the Persian water-wheel.

saraf, from Ar. word meaning to drain; in Nuba Mountains means a spring at the base of a hill.

sebākh kufri, col. Ar., village earth used as a manurial top-dressing.

se'id or *dīs*, the sedge *Cyperus rotundus* Linn. An important weed on wet clay lands.

seifi, Ar., the summer season.

sekab, a very light type of axe used for cutting dura 'qassab'.

selūka, a digging-stick with foot-rest: also applied to land cultivated by the 'selūka'.

semn, see *samn*.

senna or *senna mekka*, the yellow-flowered *Cassia acutifolia* Delile, producing the senna-pods of commerce.

seresri, a herb of the genus *Rhynchosia*.

seyal, the small tree *Acacia raddiana* Savi. Not to be confused with *Acacia seyal* Del.

shādūf, col. Ar., a hand-operated water-lifting device suited for watering plots of vegetables. It is on the seesaw model with the water container counterbalanced with a lump of clay.

shāi, Ar., tea, *Camellia sinensis* (L.) Kuntze.

shaiōt, areas of land in the Gash habitually cultivated by particular families or individuals. Also an area of land in the Gash irrigated by a cut from a 'balagh'. This meaning is going out of use.

sha'ir, Ar., barley.

shamar, fennel, *Foeniculum vulgare* Mill.

shammām, col. Ar., the sweet melon, *Cucumis melo* Linn.

sharmūt, col. Ar. from 'sharmat', to tear up, locally meat cut into small strips and sun dried for indefinite storage.

shatl or *shatla*, col. Ar., offshoots from the date-palm used for reproduction.

shaṭṭa, col. Ar., any kind of chilli, but usually *Capsicum frutescens* L. or *C. annum* L.

shebbūra, col. Ar., a sort of Scotch type of mist characteristic at Erkowīt at certain seasons of the year.

shitwi, Ar., adj. of 'shitā', winter, locally the winter season.

sidr or *nabaq*, Ar., *Ziziphus spina-christi* Lam.

sikkīn, Ar., a short, usually double-bladed knife used for harvesting dura: carried on the arm in a sheath.

silih, the herb *Blepharis persica* (Burm. F.) Kuntze.

simsim, Ar., the valuable oil-seed crop, *Sesamum orientale* Linn.

sofar iswid, the scrub bush, *Acacia drepanolobium* Harms.

soghēt, the small tree *Combretum aculeatum* Vent. Leaves greedily eaten by camels.

sorēb, the herb *Phyllanthus ninuri* Linn.

subra, col. Ar., a small circular heap of tobacco leaves undergoing fermentation and curing.

sudd, from Ar. 'sadd', pl. 'sudūd', a barrier, locally the vast bog or water prairie between Lake No and Bor.

sueiba, a mud-lined grass hut on a platform used for storing dura in rain areas.

sumeima, the grass *Aristida plumosa* Linn., also the grass *Aristida sieberiana* Trin. Relished by camels.

sunt, col. Ar., the basin-inhabiting tree *Acacia arabica* Willd., a valuable forest tree.

tabaq, col. Ar., plaited grass cover for food pots.

tabr, col. Ar., a convolvulaceous weed and good camel fodder, *Ipomoea cordofana* Choisy, in the Gezira that is a host plant of white flies that carry the virus of leaf-curl disease.

tabūl, col. Ar. from 'tabl', spice, locally a confection in the Fallata diet made from jujube berries.

tābūt, col. Ar., an Egyptian type of water-wheel discharging from the centre. Suited for low-lift work only.

tafla, col. Ar., a nitrate-bearing clay from desert hills in the northern Sudan.

tagha, the herb *Morettia phileana* DC.

tagnat, a cross-ridge for irrigation in the Gezira.

talh or *talh hamra*, Ar., the red-barked small tree *Acacia seyal* Del., used commercially for firewood.

talh beida, Ar., lit. white 'talh'. *Acacia fistula* Schweinf.

tamaleika, *Gynandropsis gynandra* (L.) Brig. Used as a vegetable.

tamām rai, Ar., lit. complete irrigation, locally a good irrigation level particularly used in connexion with Northern Province basins, contracted to 'T.R.'

tamar el fār, col. Ar., literally 'date of the field-mouse'. Used to describe poorish fodder grasses of the genus *Sporobolus*.

tamr, Ar., the fruit of the date-palm, *Phoenix dactylifera* L.

taraktarak, small tree, *Boswellia papyrifera* Hochst. The only tree in the Sudan with loose papery bark and pink flowers.

tarfa, col. Ar., *Tamarix articulata* Vahl., the common tamarisk-tree of the Gash area.

tarrād, Ar., from verb meaning to chase; earth banks thrown up parallel to the river for the better control of basin irrigation in the Northern Province.

tebeldi, the baobab-tree, *Adansonia digitata* Linn.

telebun or *bulo*, the finger millet, *Eleusine coracana* Gaertn.; one of the main grain crops of Equatoria Province.

temātim, col. Ar., the tomato, *Lycopersicum esculentum* Mill.

terās, pl. *terūs*, col. Ar., a small earth bund built with hand tools for impounding rain-water for watering rain-grown dura. Commonly used in Blue Nile, Khartoum, and Northern Provinces.

tibn, col. Ar., the straw of wheat or barley.

tīl, Ar., the deccan hemp, *Hibiscus cannabinus* L.

tīl hindi, Ar., lit. Indian hemp; the sann hemp, *Crotalaria juncea* L.

timāla, the grass *Chloris virgata* Schwartz.

tīn, Ar., the fig, *Ficus carica* L. Also clay soil.

tōb, col. Ar. from 'thawb', a garment; locally a winding cloth worn by women.

toich, a very useful Dinka word that should be admitted to the English language, used to describe the annually flooded grazing lands along the watercourses draining into the Sudd. Toiches are a feature of Equatoria Province. Every 'toich' has a 'thaiweg'.

tōm, col. Ar. from classical 'thawm'; the garlic onion, *Allium sativum* Linn.

tomām, col. Ar. from classical 'thumām'; the useful grass *Panicum turgidum* Forsk.

tombāk, col. Ar., tobacco, either *Nicotiana rustica* L. or *N. tabacum* L.

torea, a two-handed digging-hoe. A Nubian word.

tukiya, the standard length of cotton cloth in Darfur Province.

tumām, see *tomām*.

tundub, col. Ar., a leafless shrub of semi-desert areas, *Capparis decidua* Pax. Animals shelter under the bushes, and the earth comes to contain some nitrogen and is sometimes used as manure.

tūt, col. Ar., the mulberry, *Morus indicus* L.

umm asābi, Ar., lit. mother of fingers. (*a*) An indigenous grass *Dactylotenium aegyptium* Beauv., the seeds of which are used in Darfur Province and elsewhere for food. Also a good forage grass. Also called 'korēb'. (*b*) Also sometimes used as a name for the grass *Enneapogon elegans* Stapf.

umm belīla, col. Ar., the 'harīq' grass *Rottboellia exaltata* Linn.

umm bilbil, col. Ar., date beer made as 'nabīt' with the addition of sprouted and malted dura.

umm boganī, the tsetse-fly, *Glossina morsitans* Westw., that attacks cattle.

umm chirr, the excellent fodder grass *Brachiaria obtusiflora* Stapf.

umm galāgil, col. Ar., lit. mother of bells; the herb *Aristolochia bracteata* Retz.

umm khashima, col. Ar., lit. the mother of a gaping mouth; a small pit-store of the 'matmūra' type used for storing the daily requirements of grain.

umm leyūna, col. Ar., lit. mother of softness; a species of tree in the genus *Lannea* from which a fibre is obtained.

umm ritsū, the 'harīq' grass *Hyparrhenia pseudocymbaria* Stapf. Also called 'ansora'.

umm sūf, col. Ar., lit. the mother of wool; the sudd grass, *Vossia cuspidata* Griff. Also sometimes applied to *Echinochloa pyramidalis* Hichcock and Chase.

umm tak, the gay but rather poor grazing grass *Sporobolus festivus* Hochst.

usfar, the safflower, *Carthamus tinctorius* Linn.

'ushar, col. Ar., the Dead Sea apple, a common bush with milky juice and large globular fruit containing a silky floss. *Calotropis procera* Ait.

'ushub, Ar. for grass; locally a species of *Cyperus* and one of the *gizu* forage plants.

'ushūr, Ar. pl. of *'ushr*, one-tenth; locally an indigenous land-tax amounting to one-tenth of the total yield of crops.

wād lebūn, col. Ar., lit. milky valley; a bed of old grass in the Fung area suitable for 'harīq' cultivation.

wangrial, the herb *Justicia matammensis* Oliv.

warataba, applied to a bundle or 'kalleiga' of dura straw in the north, from 4 to 10 rotls.

wasuq, a flat-faced earth-levelling board for manual operation.

weika, the dried fruit or pods of 'bamia', *Hibiscus esculentus* Linn.: also applied to a semi-wild form of 'bamia'.

wena, dura cake used by Fallata people from West Africa.

weyl, same as 'buda', the root parasite *Striga hermonthica* Benth. that attacks dura.

yoi, *Gymnosporia senegalensis* Lam.

yūsef effendi, col. Ar. supposed to be proper name of first introducer to Egypt; the mandarin-tree, *Citrus nobilis* Lour.

zahhāf, Ar., a heavy log of hewn timber used for land levelling.

zakāt, Ar., a tax in Mohammedan areas for religious purposes collected from Muslims on flocks and herds, on commercial capital, and on agricultural produce.

zān, col. Ar., the small tree *Cordia abyssinica* R. Br.

zarība pl. *zarāib*, Ar., an area of land or compound enclosed by a thorn fence to keep out lions, leopards, and other wild animals.

zīr, col. Ar., a large, baked, porous earth pot mounted on a stand used for cooling the domestic water-supply. Can also be used as a filter.

zobat, same as halfa, the coarse desert grass *Desmostachya cynosuroides* Stapf, from a fancied resemblance to the date-palm inflorescence.

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